PB90-234170

Final Best Demonstrated Available Technology (BDAT) Background for Mercury-Containing Wastes D009, K106 P065, P092, and U151. Volume 17

Versar, Inc., Springfield, VA

Prepared for:

Environmental Protection Agency, Washington, DC

May 90

U.S. Department of Commerce
National Technical Information Service
NTIS

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA/530-SW-90- 059Q	2.	3. Recipient's Accession No. PB90-234 170
4. Title and Subtitle FINAL BDAT BACKGROUND DOCUMENT FOR MERCURY-CONTAINING WASTES D009, K106, P065, P092, and U151			5. Report Date May 1990 6.
7. Author(s) Rosengrant/ Labiosa			8. Performing Organization Rept. No
9. Performing Organization Name and Address U.S. EPA Office of Solid Waste 401 M. Street SW Washington, DC 20460			10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) 68-W9-0068 (G)
12. Sponsoring Organization Name and Address Versar, Inc.			13. Type of Report & Period Covered Background Document - 5/90 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This background document provides the Agency's technical support and rationale for the development of treatment standards for the constituents to be regulated for the above-mentioned wastes.

Section 2 describes the potential industries affected by regulation of these wastes, explains the potential processes generating these wastes, and presents available waste characterization data. Section 3 specifies the applicable and demonstrated treatment technologies for these wastes. Section 4 contains performance data for the demonstrated technologies, and Section 5 analyzes these performance data to determine BDAT for each waste. Sections 6 and 7 provide rationale and treatment standards, respectively.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
RELEASE UNLIMITED	UNCLASSIFIED	0
	20. Security Class (This Page) UNCLASSIFIED	22. Price 0

(See ANSI-Z39.18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)

EPA/530-SW-90-059G

PB90-234170

PB90-234170

FINAL
BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)
BACKGROUND DOCUMENT FOR

MERCURY-CONTAINING WASTES
D009, K106, P065, P092, AND U151

Larry Rosengrant, Chief
Treatment Technology Section

Jose Labiosa
Project Manager

U.S. Environmental Protection Agency
Office of Solid Waste
401 M Street, S.W.
Washington, DC 20460

May 1990

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA 22161

ACKNOWLEDGMENTS

This document was prepared for the U.S. Environmental Protection Agency, Office of Solid Waste, by Versar Inc. under Contract No. 68-W9-0068. Mr. Larry Rosengrant, Chief, Treatment Technology Section, Waste Treatment Branch, served as the EPA Program Manager during the preparation of this document and the development of treatment standards for the K061 wastewaters. The Technical Project Officer for the waste was Mr. Jose Labiosa. Mr. Steven Silverman served as Legal Advisor.

Versar personnel involved in the preparation of this document included Mr. Jerome Strauss, Program Manager; Mr. Stephen Schwartz, Assistant Program Manager; Mr. Mark Donnelly and Mr. Greg Schweer, Principal Investigators and Authors; Ms. Justine Alchowiak, Quality Assurance Officer; Ms. Martha Martin, Technical Editor; and Ms. Sally Gravely, Program Secretary.

TABLE OF CONTENTS

Section		Page No.
1.	INTRODUCTION AND SUMMARY	1-1
2.	INDUSTRIES AFFECTED AND WASTE CHARACTERIZATION	2-1
2.1	Industries Affected and Process Descriptions	2-2
2.1.1	Manufacture of Mercury Batteries	2-5
2.1.2	Chlorine Production by the Mercury Cell Process	2-6
2.1.3	Manufacture and Use of Organomercury Fungicides and Bactericides	2-10
2.2	Waste Characterization	2-11
2.2.1	K106	2-11
2.2.2	P065	2-17
2.2.3	P092	2-17
2.2.4	U151	2-17
2.2.5	D009	2-17
2.3	Determination of Waste Treatability Groups	2-18
2.3.1	Mercury Nonwastewaters	2-20
2.3.2	Radioactive Wastes Containing Mercury	2-24
2.3.3	Wastewaters	2-25
3.	APPLICABLE AND DEMONSTRATED TREATMENT TECHNOLOGIES	3-1
3.1	Applicable Treatment Technologies	3-1
3.1.1	Applicable Technologies for Nonwastewaters	3-2
3.1.2	Applicable Technologies for Wastewaters	3-6
3.2	Demonstrated Treatment Technologies	3-7
3.2.1	Demonstrated Technologies for Nonwastewaters	3-8
3.2.2	Demonstrated Technologies for Wastewaters	3-11
4.	PERFORMANCE DATA	4-1
4.1	Performance Data for Nonwastewaters	4-1
4.2	Performance Data for Wastewaters	4-3

TABLE OF CONTENTS (CONTINUED)

Section		Page No.
5.	DETERMINATION OF BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)	5-1
5.1	BDAT for Nonwastewaters	5-2
5.1.1	Inorganic Mercury Nonwastewaters - High-Mercury Subcategory	5-2
5.1.2	Inorganic Mercury Nonwastewaters - Low-Mercury Subcategory	5-8
5.1.3	Organic Mercury Nonwastewaters	5-8
5.1.4	Nonwastewaters Containing Radioactive Materials	5-9
5.2	BDAT for Wastewaters	5-10
6.	SELECTION OF REGULATED CONSTITUENTS	6-1
6.1	Nonwastewaters	6-1
6.2	Wastewaters	6-3
7.	CALCULATION OF TREATMENT STANDAKDS	7-1
7.1	Wastewaters	7-2
7.1.1	K016, P065, P092, and U151 Wastewaters	7-2
7.1.2	D009 Wastewaters	7-3
7.2	Nonwastewaters	7-3
7.2.1	K106 and U151 Nonwastewaters	7-3
7.2.2	P065 and P092 Nonwastewaters	7-5
7.2.3	D009 Nonwastewaters	7-7
7.2.4	Nonwastewaters Containing Radioactive Materials	7-5
8.	REFERENCES	8-1
APPENDIX A	QUALITY ASSURANCE/QUALITY CONTROL DATA	A-1
APPENDIX B	PROPERTIES AND MAJOR USES OF THE PRINCIPAL COMPOUNDS OF MERCURY	B-1

LIST OF TABLES

		Page No.
Table 1-1	BDAT Treatment Standard for K106, P065, P092, and U151 Wastewaters	1-10
Table 1-2	BDAT Treatment Standard for D009 Wastewaters	1-11
Table 1-3-A	BDAT Treatment Standard for K106 and U151 [All nonwastewaters in the High-Mercury Subcategory]	1-12
Table 1-3-B	BDAT Treatment Standard for K106 and U151 [Nonwastewaters that are residues from RMERC and are in the Low-Mercury Subcategory]	1-13
Table 1-3-C	BDAT Treatment Standard for K106 and U151 [Nonwastewaters that are not residues from RMERC and are in the Low Mercury Subcategory]	1-14
Table 1-4-A	BDAT Treatment Standard for P065 [All nonwastewaters that are not incinerator residues and are not residues from RMERC, regardless of mercury content	1-15
Table 1-4-B	BDAT Treatment Standard for P092 [All nonwastewaters that are not incinerator residues and are not residues from RMERC, regardless of mercury content	1-16
Table 1-4-C	BDAT Treatment Standard for P065 and P092 [Nonwastewaters that are either incinerator residues or residues from RMERC, and are in the High-Mercury Subcategory]	1-17
Table 1-4-D	BDAT Treatment Standard for P065 and P092 [Nonwastewaters that are incinerator residues (and are not residues from RMERC) that are also in the Low-Mercury Subcategory]	1-18
Table 1-4-E	BDAT Treatment Standard for P065 and P092 [Nonwastewaters that are residues from RMERC and are in the Low-Mercury Subcategory]	1-19
Table 1-5-A	BDAT Treatment Standard for D009 [All nonwastewaters that contain mercury and inorganics (and are not incinerator residues) and are also in the High-Mercury Subcategory)]	1-20

LIST OF TABLES

		Page No.
Table 1-5-B	BDAT Treatment Standard for D009 [All nonwastewaters that are inorganics (including incinerator residues and residues from RMERC) and are in the High-Mercury Subcategory]	1-21
Table 1-5-C	BDAT Treatment Standard for D009 [All nonwastewaters in the Low-Mercury Subcategory]	1-22
Table 1-6-A	BDAT Treatment Standard for D009 and U151 Elemental Mercury Contaminated with Radioactive Materials	1-23
Table 1-6-B	BDAT Treatment Standard for D009 Hydraulic Oil Contaminated with Mercury and Radioactive Materials	1-24
Table 2-1	Major Industrial Uses of Mercury	2-4
Table 2-2	Number of Producers of Chlorine Using the Mercury Cell Process Listed by State	2-7
Table 2-3	Number of Producers of Chlorine Using the Mercury Cell Process Listed by EPA Region	2-9
Table 2-4	Waste Composition Data for Untreated K106 Wastes	2-12
Table 2-5	Waste Composition Data for D009 Wastes	2-18
Table 4-1	Ore Roasting Performance Data from Thermal Recovery of Mercuric Sulfide Ores Collected by EPA at Plant A	4-4
Table 4-2	APCD Cyclone Dust Composition Data from Thermal Recovery of Mercuric Sulfide Ores Collected by EPA at Plant A	4-9
Table 4-3	Treatment Performance Data for Retorting of K106 Hydrazine Sludge Submitted by Plant B	4-10
Table 4-4	Treatment Performance Data for Retorting of K106 Hydrazine Sludge Submitted by Plant B-2	4-14
Table 4-5	Treatment Performance Data for Retorting of Mixed K071/K106 Waste from Literature Source A	4-15
Table 4-6	Treatment Performance Data for Retorting of K106 Sodium Borohydride Sludge Submitted by Plant C	4-16

LIST OF TABLES (CONTINUED)

		Page No.
Table 4-7	Treatment Performance Data for Stabilization of K106 Collected by EPA at Plant D	4-17
Table 4-8	Treatment Performance Data for Stabilization of D009 (Contaminated Soil and Debris from Natural Gas Pipeline Industry)	4-19
Table 4-9	Performance Data for Sulfide Precipitation Treatment of K071 Wastewaters Collected by EPA at Plant E	4-20
Table 5-1	Summary of Accuracy Adjustment of Treatment Data for Total Mercury Generated from Thermal Recovery Technologies	5-15
Table 5-2	Mercury Compounds Known to be Present in Listed Mercury Wastes and Their Melting Points, Boiling Points, and Behavior	5-17
Table 5-3	Summary of Accuracy Adjustment of Treatment Data for Total Mercury in Wastewaters	5-18
Table 7-1	Calculation of Numerical Treatment Standard for K106, P065, P092, and U151 Wastewaters	7-10
Table 7-2	Calculation of Numerical Treatment Standard for Low-Mercury Subcategory Nonwastewaters	7-11
Table 7-3	BDAT Treatment Standard for K106, P065, P092, and U151 Wastewaters	7-22
Table 7-4	BDAT Treatment Standard for D009 Wastewaters	7-23
Table 7-5-A	BDAT Treatment Standard for K106 and U151 [All nonwastewaters in the High-Mercury Subcategory (i.e., greater than or equal to 260 mg/kg total mercury)]	7-24
Table 7-5-B	BDAT Treatment Standard for K106 and U151 [Nonwastewaters that are residues from RMERC and are in the Low-Mercury Subcategory (i.e., less than 260 mg/kg total mercury)]	7-25

LIST OF TABLES (CONTINUED)

Page No.

Table 7-5-C BDAT Treatment Standard for K106 and U151 [Non-wastewaters that are residues from RMERC and are in the Low-Mercury Subcategory (i.e., less than 260 mg/kg total mercury)] 7-26

Table 7-6-A BDAT Treatment Standard for P065 [All nonwastewaters that are not incinerated residues and are not residues from RMERC, regardless of mercury content 7-27

Table 7-6-B BDAT Treatment Standard for P092 [All nonwastewaters that are not incinerator residues and are not residues from RMERC, regardless of mercury content] 7-28

Table 7-6-C BDAT Treatment Standard for P065 and P092 [Nonwaste-waters that are either incinerator residues or residues from RMERC, and are in the High-Mercury Subcategory (i.e., greater than or equal to 260 mg/kg total mercury)] 7-29

Table 7-6-D BDAT Treatment Standard for P065 and P092 [Nonwaste-waters that are incinerator residues (and are not residues from RMERC) that are also in the Low-Mercury Subcategory (i.e., less than 260 mg/kg total mercury)]. 7-30

Table 7-6-E BDAT Treatment Standard for P065 and P092 [Nonwaste-waters that are residues from RMERC and are in the Low-Mercury Subcategory (i.e., less than 260 mg/kg total mercury)] 7-31

Table 7-7-A BDAT Treatment Standard for D009 [All nonwastewaters that contain mercury and organics (and are not incinerator residues) and are also in the High-Mercury Subcategory (i.e., greater than or equal to 260 mg/kg total mercury)] 7-32

Table 7-7-B BDAT Treatment Standard for D009 [All nonwastewaters that are inorganics (including incinerator residues and residues from RMERC) and are in High-Mercury Subcategory (i.e., greater than or equal to 260 mg/kg total mercury)] 7-33

LIST OF TABLES (CONTINUED)

		Page No.
Table 7-7-C	BDAT Treatment Standard for D009 [All nonwastewaters in the Low-Mercury Subcategory (i.e., less than 260 mg/kg total mercury)]	7-34
Table 7-8	BDAT Treatment Standard for D009 and U151 Elemental Mercury Contaminated with Radioactive Materials	7-35
Table 7-9	BDAT Treatment Standard for D009 Hydraulic Oil Contaminated with Mercury and Radioactive Materials ...	7-36
Table A-1	Analytical Methods for K071 Wastewaters	A-2
Table A-2	Procedures or Equipment Used in Mercury Analysis When Alternatives or Equivalents Are Allowed in the SW-846 Methods	A-3
Table A-3	Matrix Spike Recoveries Used to Correct Analytical Data for K071 Mercury-Containing Wastewaters and Nonwastewaters	A-4
Table B-1	Principal Compounds of Mercury	B-2

LIST OF FIGURES

Page No.

Figure 2-1 Mercury Chemicals and Primary Uses 2-3

Figure 2-2 Processes Generating K071 and K106 Wastes 2-10

1. INTRODUCTION AND SUMMARY

Pursuant to section 3004(m) of the Resource Conservation and Recovery Act (RCRA), enacted as a part of the Hazardous and Solid Waste Amendments (HSWA) on November 8, 1984, the Environmental Protection Agency (EPA) is establishing treatment standards based on best demonstrated available technology (BDAT) for the following: mercury-containing waste identified in 40 CFR 261.32 as K106; specific mercury commercial chemical product-containing wastes identified in 40 CFR 261.33 as P065, P092, and U151; and wastes identified in 40 CFR 261.24 as D009 exhibiting the characteristic of TCLP toxicity for mercury (see 54 FR 11798, March 29, 1990, which replaces the existing EP leach test with the TCLP for all hazardous wastes listed under 40 CFR 261.24). Compliance with these treatment standards is a prerequisite for the placement of these wastes in facilities designated as land disposal units according to 40 CFR Part 268. The effective date of final promulgated treatment standards for these wastes is August 8, 1990.

This background document presents the Agency's rationale and technical support for developing regulatory treatment standards for the mercury-containing wastes identified above. Section 2 describes the potential industries affected by regulation of these wastes, explains the potential processes generating these wastes, and presents available waste characterization data. There may be other industrial operations not addressed in Section 2 that may generate wastes meeting the criteria for mercury hazardous wastes under 40 CFR Part 261. If so, these other wastes are also subject to the restrictions EPA is promulgating today under 40 CFR Part 268. Section 3 specifies the applicable and demonstrated treatment technologies for these wastes. Section 4 contains performance data for the demonstrated technologies, and Section 5 analyzes these performance data to determine BDAT for each waste. Section 6 presents the rationale for selection of regulated constituents,

and Section 7 presents the BDAT treatment standards and their calculation for the regulated constituents selected for each waste.

EPA's promulgated methodology for developing BDAT treatment standards is described in two separate documents: Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT") (USEPA 1988a) and Methodology for Developing BDAT Treatment Standards (USEPA 1989a). Facilities unable to meet the treatment standards can petition the Administrator for a variance from the treatment standards. The petition process to be followed in requesting a variance from the BDAT treatment standards and the information required are discussed in the methodology document.

The Agency classifies hazardous wastes as either wastewaters or nonwastewaters. For the purpose of determining the applicability of the treatment standards, wastewaters are defined as wastes containing less than 1 percent (weight basis) total suspended solids* and less than 1 percent (weight basis) total organic carbon (TOC). Wastes not meeting this definition must comply with the treatment standards for nonwastewaters.

For all wastewater forms of K106, P065, P092, and U151, EPA is promulgating a treatment standard of 0.030 mg/l. The treatment standard is based on the performance of sulfide precipitation treatment of K071 wastewaters. Some mercury-containing wastewaters may require additional or different treatment trains in order to treat other metals or organics

---

* The term "total suspended solids" (TSS) clarifies EPA's previously used terminology of "total solids" and "filterable solids." Specifically, the quantity of total suspended solids is measured by Method 209c (Total Suspended Solids Dried at 103°C to 105°C) in Standard Methods for the Examination of Water and Wastewater, 15th Edition (APHA, AWWA, and WPCF 1985).

that may interfere with the treatment of mercury. Pretreatment by a. oxidation step (with reagents such as hydrogen peroxide or sodium hypochlorite) or incineration may be necessary to treat the organics in P092 wastewaters. Pretreatment by aqueous chemical deactivation or by incineration in specially-designed thermal treatment units may be necessary to treat reactive constituents in P065 wastewaters. The treatment standard for K106, P065, P092, and U151 wastewaters is presented in Table 1-1, at the end of this section.

For D009 wastewaters, EPA proposed two regulatory options. One regulatory option would have required treatment of these wastes to comply with a treatment standard of 0.030 mg/l. The second regulatory option was to require treatment of these wastes to meet a treatment level of 0.20 mg/l (the toxic characteristic level for mercury). In the proposed rule, EPA solicited comments on the merits of each of these approaches. The Agency received many comments and reviewed each carefully before deciding to regulate D009 wastewaters at the characteristic level of 0.20 mg/l. Even though the data available to EPA indicate that a treatment standard of 0.030 mg/l is achievable for many D009 wastewaters, EPA is adopting the characteristic level of 0.20 mg/l as the treatment standard for D009 wastes for reasons outlined in Section III.D of today's final rule for Third Third wastes. In addition, available data indicate that even the most difficult to treat D009 wastewaters can be treated to the characteristic level of 0.20 mg/l. The treatment standard for D009 wastewaters is presented in Table 1-2.

For nonwastewater forms of K106, U151, P065, P092, and D009, EPA is establishing two general mercury subcategories: a High-Mercury Subcategory and a Low-Mercury Subcategory. A total mercury concentration of 260 mg/kg has been established to classify these mercury wastes into one of these two subcategories and to determine compliance with the treatment

standards. The 260 mg/kg cutoff level is based on the mercury concentrations of an untreated mixed K071/K106 waste being retorted/roasted. (See Section 7 for a detailed explanation of the derivation of the 260 mg/kg cutoff level.)

Also, the Agency is setting additional restrictions for the disposal of treatment residues resulting from incinerators, retorters, or roasters. These additional restrictions are expressed as a requirement for further treatment (e.g., further retorting) or a requirement for compliance with a maximum concentration of leachable mercury acceptable for disposal (e.g., TCLP mercury leachate below 0.20 mg/l for residues from retorters and roasters). EPA believes these additional requirements will adequately minimize the commenters' concern of having a more leachable mercury in incinerated, retorted, or roasted wastes. The Agency's authority to impose these additional conditions comes directly under Section 3004(m).

For nonwastewater forms of K106 and U151 in the high-mercury subcategory, EPA is promulgating a treatment standard of retorting/roasting. Nonwastewater residues from retorting/roasting are not prohibited from land disposal unless they leach mercury above 0.20 mg/l, as measured by TCLP. Nonwastewater residues unacceptable for land disposal (i.e., those that leach mercury at levels exceeding 0.20 mg/l) are required to comply with the appropriate standards (i.e., high- or low-mercury subcategory) as a prerequisite for land disposal. It is impermissible to dilute a High Mercury Subcategory waste to reduce the concentration to less than 260 mg/kg.

For nonwastewater forms of K106 and U151 that are not residues from retorting/roasting and are in the Low-Mercury Subcategory, EPA is transferring the performance of acid leaching treatment followed by sulfide chemical precipitation of K071 nonwastewaters to these inorganic

mercury nonwastewaters. The BDAT treatment standard for these wastes is 0.025 mg/l mercury as measured by the TCLP leachate. Residues from this acid leaching process must be evaluated for mercury content to determine whether they must undergo roasting/retorting. Treatment standards for K106 and U151 nonwastewaters are summarized in Tables 1-3-A, 1-3-B, and 1-3-C.

The Agency proposed creating a new subcategory for K071 nonwastewaters identified as the K071 High-Mercury Subcategory (greater than or equal to 16 mg/kg total mercury). For K071 nonwastewaters in the High-Mercury Subcategory, the proposed treatment standard was retorting or roasting as a method of treatment. EPA received several comments on this proposed revision and has decided, upon further review, not to adopt the proposed revisions. The existing BDAT standard for K071 nonwastewaters is retained (53 FR 31166). However, this decision does not preclude the Agency from revising the treatment standard in the future if new data become available.

For P065 and P092 nonwastewaters, the BDAT treatment standard is incineration for the carbon-mercury compounds. Alternatively, EPA is promulgating retorting or roasting for P092 nonwastewater. Incinerator nonwastewater residues equal to or above 260 mg/kg mercury are considered to be in the High-Mercury Subcategory and must be recovered by retorting or roasting. Incinerator nonwastewater residues below 260 mg/kg are considered to belong to the Low-Mercury Subcategory and are not prohibited from land disposal unless they leach mercury above 0.025 mg/l (as measured by the TCLP). Nonwastewater residues from retorting/ roasting operations are not prohibited from land disposal unless they leach mercury equal to or above 0.20 mg/l (as measured by the TCLP). Retorting/roasting residues unacceptable for land disposal (i.e., above 0.20 mg/l) are required to comply with the applicable standards for the High- or Low-Mercury Subcategory. P065 and P092 scrubber waters generated from incineration, roasting, or retorting must comply with the

0.030 mg/l wastewater standard (see Table 1-1), which is based on the same performance data used to develop the existing K071 wastewater standard. Treatment standards for P065 and P092 nonwastewaters are shown in Tables 1-4-A through 1-4-E.

The BDAT treatment standard for D009 High-Mercury Subcategory nonwastewaters (i.e., those that contain greater than or equal to 260 mg/kg of mercury) is a combination of the treatment standards for the high-mercury inorganic nonwastewaters and the organic mercury nonwastewaters. EPA has determined that retorting or roasting represents BDAT for D009 high-mercury nonwastewaters containing elemental mercury or inorganic mercury compounds. Although D009 wastes that contain organomercury constituents or that contain mercury contaminated with organics can also be retorted/roasted, a pretreatment step may be necessary to allow recovery of mercury. Incineration has been determined to be BDAT for organics in this type of D009 nonwastewater and also for nonwastewater containing organomercury constituents. Since incineration cannot destroy mercury, but instead concentrates mercury in scrubber water or ash to levels not expected to be acceptable for land disposal, the Agency has established additional requirements for the mercury in these residuals. As a result, the treatment standard for D009 high-mercury nonwastewaters is expressed as either retorting/roasting or incineration. Incinerator nonwastewater residues that contain concentrations of mercury greater than or equal to 260 mg/kg are considered to belong to the High-Mercury Subcategory and must be retorted/roasted prior to disposal. Nonwastewater residues from retorting/roasting operations are not prohibited from land disposal unless they leach mercury above 0.20 mg/l (as measured by the TCLP). Retorting/roasting residues unacceptable for disposal (i.e., above 0.20 mg/l TCLP) are required to comply with the appropriate standards for the D009 High- or Low-Mercury Subcategory.

For D009 low-mercury nonwastewaters, EPA is promulgating a treatment standard of 0.20 mg/l, as measured by TCLP (i.e., the toxic characteristic level for mercury). EPA received very few data on the proposed standards for D009 wastes. These data were determined to represent the treatment of mercury-containing wastes failing the listing criteria for D009, as measured by TCLP. However, several commenters supported the regulatory alternative for setting treatment standards for D009 wastes at the characteristic level. Although data available to EPA indicate that the lower proposed standard (0.025 mg/l) should be achievable for D009, EPA acknowledges the commenters' concerns that a large, diverse number of wastes that qualify as D009 may not be represented by K071 performance data. EPA is thus in withdrawing the proposed 0.025 mg/l level (based on K071 performance data). Based on the available data, EPA believes D009 wastes can be treated to the characteristic level by treatment technologies such as stabilization or amalgamation with zinc or tin. EPA is instead promulgating a treatment standard of 0.20 mg/l mercury, as measured by TCLP, for these nonmercury nonwastewaters. BDAT treatment standards for D009 nonwastewaters are summarized in Tables 1-5-A, 1-5-B, and 1-5-C.

Several commenters identified a list of D009 wastes that the commenters believe meet EPA's criteria for contaminated soil and debris. The commenters believe that these D009 wastes are not amenable to retorting/roasting; however, they have proposed alternative treatment standards based on the use of a chemical decontamination technology. EPA has been unable to determine whether the alternative chemical decontamination technology represents BDAT for these wastes. The Agency believes such demonstration can be made as part of the ongoing regulatory efforts for contaminated soil and debris. If the technology is demonstrated, EPA may publish revisions to today's standards for these wastes.

Information provided to EPA by the U.S. Department of Energy (DOE) indicates the generation of two particular D009 mixed radioactive/ hazardous wastes that contain mercury. This information also suggests that the BDAT technologies and standards for the corresponding nonradioactive wastes may not be applicable to these mixed wastes. The Agency has therefore promulgated alternative treatment standards for these wastes.

One of the mixed wastes identified is waste elemental mercury contaminated with radioactive tritium (a radioisotope of hydrogen). These wastes are often identified as D009 or U151. EPA has determined that recovery technologies do not represent BDAT for this waste because the Agency lacks data indicating that these processes would be able to separate the mercury from the radioactive material, resulting in recovery of reusable mercury. EPA has identified amalgamation with zinc as a technology that provides significant treatment to these wastes in terms of air emissions (thus greatly reducing the toxicity of these wastes) and also potentially reduces the leachability of mercury by amalgamation. The BDAT for these wastes is amalgamation with zinc, and the treatment standard is amalgamation with zinc as a method of treatment.

The second mixed waste identified is a spent hydraulic oil contaminated with mercury and radioactive tritium. EPA determined that incineration represents BDAT for this waste because incineration is demonstrated for nonradioactive organic mercury nonwastewaters. However, the Agency has modified the nonradioactive organic mercury nonwastewaters standard for this waste by withdrawing the requirement to recover mercury from the inorganic residues generated from incineration of this waste. The Agency is requiring that nonwastewater incineration residues (incinerator ash and wastewater treatment sludge generated from treatment of incineration scrubber waters) comply with a TCLP mercury standard of

0.20 mg/l and that incineration scrubber waters meet the 0.20 mg/l total concentration mercury standard for mercury-containing wastewaters. Treatment standards for mixed radioactive/hazardous mercury wastes are presented in Tables 1-6-A and 1-6-B.

EPA is specifying further that, for treatment standards expressed as methods of treatment, certain regulatory conditions must be met. Incinerators must be operated in accordance with the provisions under 40 CFR Part 264, Subpart O, or Part 265, Subpart O. Also, EPA is specifying that, as part of the BDAT, the retorting/roasting unit (or facility) must be subject to one or more of the following: (1) NESHAP for mercury, (2) a PDS permit, or (3) a State permit that establishes emission limitations pursuant to Section 302 of the Clean Air Act for mercury.

The Agency believes that with such air emission controls retorting is a treatment technology that minimizes threats to human health and the environment and so satisfies the requirements of section 3004(m). (The Agency's authority to impose these conditions on performance of a mercury retorting device comes directly from its authority under section 3004(m) to establish methods of treatment. EPA is indicating here that part of the designated method includes operating pursuant to standards that prevent cross-media contamination. Such standards are enforceable under RCRA pursuant to the authority in section 3008(a).)

Table 1-1 BDAT Treatment Standard for K106, P065, P092, and U151 Wastewaters

Regulated constituent	Maximum for any single grab sample Total composition (mg/l)
Mercury	0.030

Table 1-2 BDAT Treatment Standard for D009 Wastewaters

Regulated constituent	Maximum for any single grab sample Total composition (mg/l)
Mercury	0.20

Table 1-3-A BDAT Treatment Standard for K106 and U151
[All nonwastewaters in the High-Mercury
Subcategory (i.e., greater than or equal to
260 mg/kg total mercury)]

ROASTING OR RETORTING (RMERC)[a]

[a](RMERC) retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery. The retorting or roasting unit (or facility) must be subject to one or more of the following: (a) a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for mercury; (b) a Best Available Control Technology (BACT) or a Lowest Achievable Emission Rate (LAER) standard for mercury imposed pursuant to a Prevention of Significant Deterioration (PSD) permit; or (c) a State permit that establishes emission limitations (within meaning of Section 302 of the Clean air Act) for mercury. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (e.g., High- or Low-Mercury Subcategories).

Table 1-3-B BDAT Treatment Standard for K106 and U151
[Nonwastewaters that are residues from RMERC and are in the Low-Mercury Subcategory (i.e., less than 260 mg/kg total mercury)]

Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.20

Table 1-3-C BDAT Treatment Standard for K106 and U151
[Nonwastewaters that are not residues from RMERC and are in the Low-Mercury Subcategory (i.e., less than 260 mg/kg total mercury)]

Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.025

Table 1-4-A BDAT Treatment Standard for P065
[All nonwastewaters that are not incinerator residues
and are not residues from RMERC, regardless of mercury content]

INCINERATION OF WASTES WITH ORGANICS AND MERCURY (IMERC)[a]

[a](IMERC) incineration of wastes containing organics and mercury in units operated in accordance with the technical operating requirements of 40 CFR 264 Subpart O and 265 Subpart O). All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (i.e., High- or Low-Mercury Subcategories.)

Table 1-4-B BDAT Treatment Standard for P092
[All nonwastewaters that are not incinerator residues
and are not residues from RMERC, regardless of mercury content]

INCINERATION OF WASTES WITH ORGANICS AND MERCURY (IMERC)[a] OR ROASTING/RETORTING (RMERC)[b]

[a](IMERC) incineration of wastes containing organics and mercury in units operated in accordance with the technical operating requirements of 40 CFR 264 Subpart O and 265 Subpart O). All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (i.e., High- or Low-Mercury Subcategories.)

[b](RMERC) retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery. The retorting or roasting unit (or facility) must be subject to one or more of the following: (a) a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for mercury; (b) a Best Available Control Technology (BACT) or a Lowest Achievable Emission Rate (LAER) standard for mercury imposed pursuant to a Prevention of Significant Deterioration (PSD) permit; or (c) a State permit that establishes emission limitations (within meaning of Section 302 of the Clean Air Act) for mercury. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (e.g., High- or Low-Mercury Subcategories).

Table 1-4-C BDAT Treatment Standard for P065 and P092
[Nonwastewaters that are either incinerator residues or residues from RMERC, and are in the High-Mercury Subcategory (i.e., greater than or equal to 260 mg/kg total mercury)]

ROASTING OR RETORTING (RMERC)[a]

[a](RMERC) retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery. The retorting or roasting unit (or facility) must be subject to one or more of the following: (a) a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for mercury; (b) a Best Available Control Technology (BACT) or a Lowest Achievable Emission Rate (LAER) standard for mercury imposed pursuant to a Prevention of Significant Deterioration (PSD) permit; or (c) a State permit that establishes emission limitations (within meaning of Section 302 of the Clean air Act) for mercury. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (e.g., High- or Low-Mercury Subcategories).

Table 1-4-D BDAT Treatment Standard for P065 and P092
[Nonwastewaters that are incinerator residues (and are not residues from RMERC) that are also in the Low-Mercury Subcategory (i.e., less than 260 mg/kg total mercury)]

Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.025

Table 1-4-E BDAT Treatment Standard for P065 and P092
[Nonwastewaters that are residues from RMERC and are in the Low-Mercury Subcategory (i.e., less than 260 mg/kg total mercury)]

Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.20

Table 1-5-A BDAT Treatment Standard for D009
[All nonwastewaters that contain mercury and organics (and are not incinerator residues) and are also in the High-Mercury Subcategory (i.e., greater than or equal to 260 mg/kg total mercury)]

INCINERATION OF WASTES WITH ORGANICS AND MERCURY (IMERC)[a] OR ROASTING/RETORTING (RMERC)[b]

[a](IMERC) incineration of wastes containing organics and mercury in units operated in accordance with the technical operating requirements of 40 CFR 264 Subpart O and 265 Subpart O. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (e.g., High- or Low-Mercury Subcategories.)

[b](RMERC) retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery. The retorting or roasting unit (or facility) must be subject to one or more of the following: (a) a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for mercury; (b) a Best Available Control Technology (BACT) or a Lowest Achievable Emission Rate (LAER) standard for mercury imposed pursuant to a Prevention of Significant Deterioration (PSD) permit; or (c) a State permit that established emission limitations (within meaning of Section 302 of the Clean Air Act) for mercury. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (e.g., High- or Low-Mercury Subcategories).

Table 1-5-B BDAT Treatment Standard for D009
[All nonwastewaters that are inorganics (including incinerator residues and residues from RMERC) and are in the High-Mercury Subcategory (i.e., greater than or equal to 260 mg/kg total mercury)]

ROASTING OR RETORTING (RMERC)[a]

[a](RMERC) retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery. The retorting or roasting unit (or facility) must be subject to one or more of the following: (a) a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for mercury; (b) a Best Available Control Technology (BACT) or a Lowest Achievable Emission Rate (LAER) standard for mercury imposed pursuant to a Prevention of Significant Deterioration (PSD) permit; or (c) a State permit that established emission limitations (within meaning of Section 302 of the Clean Air Act) for mercury. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (e.g., High- or Low-Mercury Subcategories).

Table 1-5-C BDAT Treatment Standard for D009
[All nonwastewaters in the Low-Mercury Subcategory
(i.e., less than 260 mg/kg total mercury)]

Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.20

Table 1-6-A BDAT Treatment Standard for D009 and U151
Elemental Mercury Contaminated with Radioactive Materials

AMALGAMATION WITH ZINC AS A METHOD OF TREATMENT FOR NONWASTEWATERS[a]

[a]Any wastewaters must comply with the appropriate wastewater standard (for D009 or U151).

Table 1-6-B BDAT Treatment Standard for D009 Hydraulic Oil Contaminated with Mercury and Radioactive Materials

INCINERATION AS A METHOD OF TREATMENT WITH INCINERATOR RESIDUES MEETING 0.20 MG/L, AS MEASURED BY THE TCLP

2. INDUSTRIES AFFECTED AND WASTE CHARACTERIZATION

As discussed in Section 1, those wastes listed in 40 CFR 261.24, 261.32, and 261.33 are subject to the land disposal restriction provisions of RCRA. This document discusses the mercury-containing wastes K106, P065, P092, U151, and D009. This section describes the potential industries affected by land disposal restrictions for these mercury-containing wastes and the potential processes generating the wastes, summarizes available waste characterization data, and discusses applicable treatability groups. Other operations may be generating mercury wastes not covered in this section. However, if their wastes meet any of the descriptions in 40 CFR 261.44, 261.32, and 261.33, their wastes may also be subject to the land disposal restrictions in 40 CFR Part 268.

Within the industry-specific listing of hazardous wastes in Section 261.32 are the following three wastes generated by the chlorine industry:

K071: Brine purification muds from the mercury cell process in chlorine production, where separately prepurified brine is not used.

K073: Chlorinated hydrocarbon waste from the purification step of the diaphragm cell process using graphite anodes in chlorine production.

K106: Wastewater treatment sludge from the mercury cell process in chlorine production.

The listed waste K071 was regulated previously with the First Third restricted wastes (USEPA 1988b). Although nonwastewater treatment standards for this waste were proposed for revision under the Third Third rule, EPA has decided to retain the existing standards and not to adopt the proposed revisions. The listed waste K071 is discussed in a separate First Third background document (USEPA 1988b). The listed waste K073 is discussed in a separate Third Third background document (USEPA 1989c).

This background document addresses the development of treatment standards for K106.

The following wastes are listed in 40 CFR Section 261.33 for mercury:

P065: Mercury fulminate
P092: Phenylmercuric acetate
U151: Mercury

The U and P wastes of concern (U151, P065, and P092) are generated as discarded chemical products, off-specification products, container residues, or contaminated soil, water, or other debris resulting from the cleanup of leaks or spills of products or off-specification products. This background document addresses the development of treatment standards for P065, P092, and U151.

This document also discusses the development of treatment standards for wastes listed in 40 CFR 261.24 as D009. D009 is any waste that is characteristically hazardous based on the concentration of mercury in the leachate as determined by the Toxicity Characteristic Leaching Procedure (TCLP)(see 54 FR 11798, March 29, 1990). D009 wastes can be generated in many different forms by many different industrial processes.

2.1 Industries Affected and Process Descriptions

Metallic mercury and inorganic and organic mercury compounds are used in many industries. Figure 2-1 summarizes the major manufacturing process chemistry and end uses of mercury compounds. Table 2-1 presents the major industrial end users of mercury listed in decreasing order of their mercury consumption in 1983.

The largest use of mercury, amounting to 48 percent of all mercury used in 1983 (the last year for which statistics were available) is in

Table 2-1 Major Industrial Uses of Mercury

Industry	SIC Codes	Amount of mercury used (thousands of lb)
Electrical products (batteries, lamps, wiring and switching devices, etc.)	3600	2,050
Chlorine production	2812	612
Paints	2851	460
Instruments (thermometers, manometers, barometers, etc.)	3820	187
Dental supplies	3843	121
Catalysts, miscellaneous	2819, 2869	37
Other (pharmaceuticals, pigments, lab analyses, etc.)	2833, 2816, others	270

Source: U.S. Bureau of Mines 1985.

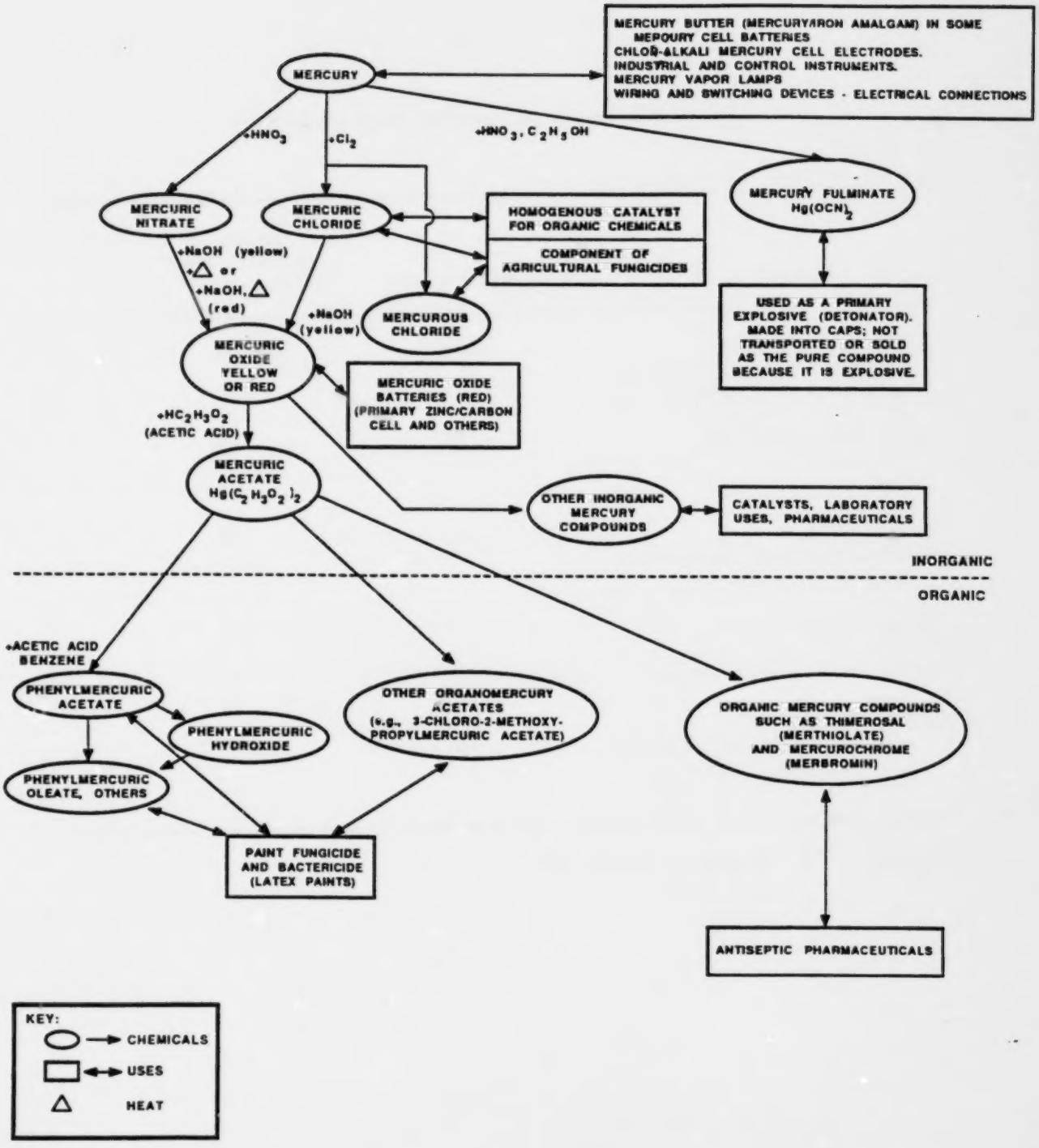

FIGURE 2-1. MERCURY CHEMICALS AND PRIMARY USES

the manufacture of mercuric oxide batteries, primarily the mercuric oxide/zinc dry cell. Mercuric oxide is used as the cathode material in these batteries. Metallic mercury is often amalgamated with other metals (e.g., silver and zinc) and used as the anode material in batteries. The production of batteries using mercury and mercuric oxide is discussed in Section 2.1.1.

The second largest use of mercury, amounting to 16 percent of that used in 1983, is in the manufacture of chlorine by the mercury cell process. Metallic mercury is used in this process as the cathode material in electrolytic cells that decompose a sodium chloride brine solution into sodium hydroxide and chlorine. This process is discussed in Section 2.1.2.

The next largest use of mercury is as a fungicide and bactericide in latex paints. The primary compound used in this application is phenylmercuric acetate. Other organic mercury compounds are also used. Phenylmercuric acetate is made from mercuric acetate, as shown in Figure 2-1.

Other uses of mercury metal are in electrical equipment such as industrial control instruments, in mercury vapor lamps, in wiring and switching devices as an electrical connection, and in barometers and thermometers. Mercury compounds are also used as initiating explosives (mercury fulminate), as homogeneous catalysts (mercuric chloride), as components of agricultural fungicides (mercurous chloride and mercuric chloride), and as antiseptic pharmaceuticals (various organic and inorganic mercury compounds).

2.1.1 Manufacture of Mercury Batteries

Many batteries contain metallic mercury or mercuric oxide as components. Mercury cell batteries (mercuric oxide:zinc cells) consist

of a mercuric oxide powder as the cathode, a mercury/zinc amalgam as the anode, and an alkaline electrolyte solution (usually potassium hydroxide). Mercuric oxide is also used in other types of batteries as a cathode material. Both nonwastewaters and wastewaters containing mercury can be generated from battery manufacturing. Wastewaters containing mercury can be generated from cleanup of spills of mercuric oxide or metallic mercury or as water washes of processing equipment. Nonwastewaters that can be generated include off-specification batteries, spilled or off-specification mercuric oxide, spilled mercury, or wastewater treatment sludges generated from the treatment of mercury-containing wastewaters.

2.1.2 Chlorine Production by the Mercury Cell Process

Chlorine is produced primarily from the electrolytic decomposition of either sodium chloride or potassium chloride, from which the coproducts are sodium hydroxide (caustic soda) or potassium hydroxide. All of the caustic soda and potassium hydroxide and over 90 percent of the chlorine produced in the United States are made by the electrolytic decomposition of sodium chloride or potassium chloride. Chlorine is also produced by other processes, including nonelectrolytic oxidation of hydrochloric acid (HCl), the production of sodium metal, and the electrolytic production of magnesium metal from molten magnesium chloride.

Three types of electrolytic cells are in commercial use for the production of alkalies and chlorine: the mercury cell, the diaphragm cell, and the membrane cell. The listed waste K106 is generated in chlorine production by the mercury cell process. The Agency estimates that there are 20 facilities that produce chlorine by the mercury cell process and may generate K106 waste. EPA also estimates that 14 of these facilities do not use prepurified salt and thus also may generate K071 waste. The locations of these facilities are provided in Table 2-2,

Table 2-2 Number of Producers of Chlorine Using the Mercury Cell Process Listed by State

State (EPA Region)	Number of producers	Number that do not use prepurified salt
Alabama (IV)	3	3
Delaware (III)	1	1
Georgia (IV)	2	1
Kentucky (IV)	1	1
Louisiana (VI)	2	1
Maine (I)	1	1
New York (II)	2	1
North Carolina (IV)	1	1
Ohio (V)	1	1
Tennessee (IV)	1	1
Texas (VI)	1	0
Washington (X)	1	1
West Virginia (III)	2	0
Wisconsin (V)	1	1
Total	20	14

Source: SRI 1989.

listed by State, and in Table 2-3, listed by EPA Region. Chlorine producers fall under SIC Code 2812, Alkalies and Chlorine.

In chlorine production by the mercury cell process, a saturated salt brine solution is prepared by dissolving sodium chloride, usually in the form of rock salt (although prepurified salt is sometimes used), in the depleted brine solution recycled from the mercury cells (see Figure 2-2). The brine is purified (unless prepurified salt is used) by addition of sodium carbonate and sodium hydroxide to precipitate any dissolved impurities. Solids (muds) generated in brine purification are the listed waste K071. The purified saturated brine is fed to the mercury cells, where electrolytic decomposition into sodium hydroxide and chlorine occurs. The chlorine is subsequently purified. If potassium chloride is used as a feed to the process, potassium hydroxide and chlorine are produced.

Sources of wastewater from the production of chlorine by the mercury cell process include (1) brine that is bled from the end boxes of the mercury cells; (2) wastewater collected from the floor of or basement below the room containing the mercury cells, generated from periodic washdown of the cell room floor and equipment; and (3) any other wastewaters generated by the plant that may contain mercury. Treatment of plant process wastewaters by chemical precipitation generates a wastewater treatment sludge, which is the listed waste K106. With the exception of one mercury cell chlorine production facility, K106 is generated by sulfide precipitation. One facility currently uses hydrazine to treat mercury-contaminated wastewaters; this process generates a mercurous hydroxide compound. In the past, K106 was generated by chemical reduction treatment of mercury-contaminated wastewaters using sodium borohydride. EPA is uncertain whether sodium borohydride is still used to treat mercury-contaminated wastewaters.

Table 2-3 Number of Producers of Chlorine Using the Mercury Cell Process Listed by EPA Region

EPA Region	Number of producers	Number that do not use prepurified salt
I	1	1
II	2	1
III	3	1
IV	8	7
V	2	2
VI	3	1
X	1	1
Total	20	14

Source: SRI 1989.

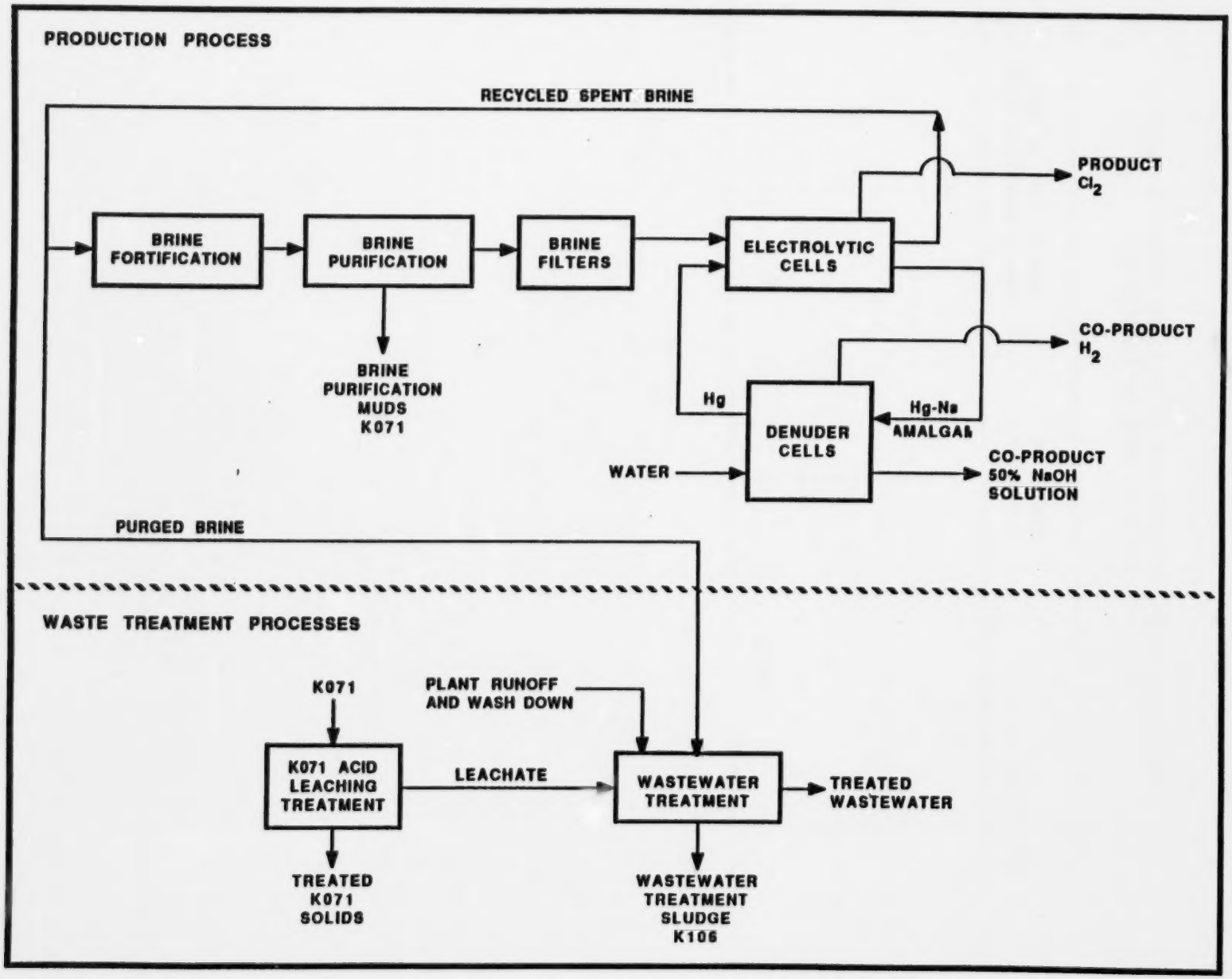

FIGURE 2-2. PROCESSES GENERATING K071 AND K106 WASTES

2.1.3 Manufacture and Use of Organomercury Fungicides and Bactericides

The Agency has information that phenylmercuric acetate (P092) and phenylmercuric oleate are produced by Cosan Chemical in Carlstadt, New Jersey (SRI 1989). These compounds (and other phenylmercury compounds) are used as bactericides in latex paint formulations. Phenylmercuric acetate is manufactured by reaction of mercuric acetate with benzene. Phenylmercuric acetate can be used as a starting material in the production of many other phenylmercury compounds.

In paint formulation operations, pigments are mixed with solvents, carriers, and other additives. Phenylmercury compounds are added in very small quantities (less than 1 percent) as preservatives for latex paints. Washing of equipment used in paint formulation may result in the generation of wastes containing organomercury compounds such as phenylmercuric acetate. These wastes sometimes contain other organic compounds as well.

2.2 Waste Characterization

2.2.1 K106

EPA has waste characterization data for both K106 generated by sulfide treatment and K106 generated by hydrazine treatment. The approximate concentrations of the major constituents for both of these K106 forms were determined from EPA analysis of the waste and other characterization data and information submitted by industry to EPA. As summarized in Table 2-4, both forms of K106 are primarily composed of water and diatomaceous earth filter aid. The K106 generated by sulfide precipitation contains approximately 4.4 percent mercury on average, as mercuric sulfide; the K106 generated by hydrazine treatment contains approximately 0.5 percent mercury on average, as mercurous hydroxide.

Table 2-4 Waste Composition Data for Untreated K106 Wastes

Constituent	Untreated K106 waste concentration				
	(a) (mg/kg)	(b) (mg/kg)	(c) (mg/kg)	(c) (mg/kg)	(c) (mg/kg)
BDAT List Metals					
Antimony	<3.8	-	-	-	-
Arsenic	1.1	-	-	-	-
Barium	74	-	-	-	-
Beryllium	<0.1	-	-	-	-
Cadmium	2.3	-	-	-	-
Chromium	6.3	-	-	-	-
Copper	133	-	-	-	-
Lead	50	-	-	-	-
Mercury	25,900	2000 - 150,000	4300 - 17,000	55,000 - 146,000	5000 - 7000
Nickel	14	-	-	-	-
Selenium	<5.0	-	-	-	-
Silver	131	-	-	-	-
Thallium	<8.6	-	-	-	-
Vanadium	0.46	-	-	-	-
Zinc	443	-	-	-	-
Other Analyses					
Aluminum	168	-	-	-	-
Calcium	478	-	-	-	-
Cobalt	1.3	-	-	-	-
Iron	833	-	400	-	-
Magnesium	132	-	-	-	-
Manganese	6.5	-	-	-	-
Potassium	7,870	-	-	-	-
Sodium	4,120	-	-	-	-
Tin	<5.5	-	-	-	-
Sulfide	-	-	-	-	-
Total solids	41.5	-	-	-	-
Total suspended solids	-	-	-	-	-
Paint filter test	Pass	-	-	-	-
Diatomaceous earth	-	-	700,000 - 950,000	800,000 - 950,000	-
Water	-	-	5000 - 20,000	50,000 - 150,000	-
Sodium chloride	-	-	80,000 - 100,000	-	-

- = Not analyzed.

Sources: (a) USEPA 1988c.
(b) Versar 1986.
(c) USEPA 1985.
(d) The Chlorine Institute 1988.

Table 2-4 (continued)

Constituent	Untreated K106 waste concentration					
	(d)		(d)		(d)	
	Total (mg/kg)	TCLP (mg/kg)	Total (mg/kg)	EP Toxicity (mg/kg)	Total (mg/kg)	TCLP (mg/kg)
BDAT List Metals						
Antimony	<52	0.175	-	-	<0.005	<0.005
Arsenic	52	<0.076	0.7	0.003	0.407	0.018
Barium	119	0.551	6.0	0.06	175	0.12
Beryllium	<1.4	<0.004	2.3	-	<1.5	<0.005
Cadmium	15	0.03	2.3	0.03	5.0	<0.01
Chromium	223	0.128	4.6	0.024	36	<0.01
Copper	861	<0.032	-	-	345	0.07
Lead	456	1.59	111	-	135	0.05
Mercury	62,500	0.045	-	0.006	38,300	2.73
Nickel	138	0.681	1.0	0.045	260	<0.01
Selenium	1.7	<0.05	0.3	0.001	<0.005	<0.005
Silver	12	<0.02	2.8	0.0027	10	<0.01
Thallium	-	-	-	-	<5	<0.05
Vanadium	9.0	<0.016	-	-	<5	<0.02
Zinc	3940	15.2	-	-	128	0.05
Other Analyses						
Aluminum	-	-	-	-	-	-
Calcium	-	-	-	-	-	-
Cobalt	-	-	-	-	-	-
Iron	-	-	-	-	-	-
Magnesium	-	-	-	-	-	-
Manganese	-	-	-	-	-	-
Potassium	-	-	-	-	-	-
Sodium	-	-	-	-	-	-
Tin	-	-	-	-	-	-
Sulfide	-	-	-	-	7,493	196
Total solids	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-
Paint filter test	-	-	-	-	-	-
Diatomaceous earth	-	-	-	-	-	-
Water	50,000	-	540,000	-	440,000	-
Sodium chloride	-	-	-	-	-	-
Chloride	-	-	5910	-	<60	-
Sulfate	-	-	3090	-	5.0	-
Total organic carbon	-	-	-	-	-	-
Oil and grease	-	-	9.6	-	4495	-

- = Not analyzed.

Sources: (a) USEPA 1988c.
(b) Versar 1986.
(c) USEPA 1985.
(d) The Chlorine Institute 1988.

Table 2-4 (continued)

Constituent	Untreated K106 waste concentration					
	(d)		(d)		(d)	
	Total (mg/kg)	TCLP (mg/kg)	Total (mg/kg)	EP Toxicity (mg/kg)	Total (mg/kg)	TCLP (mg/kg)
BDAT List Metals						
Antimony	<6	<0.06	-	-	0.2	-
Arsenic	8.0	0.14	3.0	<0.005	0.1	0.01
Barium	71	0.21	5.0	<0.03	3.0	2.5
Beryllium	<0.2	<0.002	-	-	-	-
Cadmium	2.0	<0.005	0.4	<0.005	-	0.01
Chromium	70	<0.007	750	0.6	3.0	0.01
Copper	361	<0.03	-	-	250	-
Lead	142	<0.05	4.0	<0.5	100	0.25
Mercury	161,000	3.88	20,000	<0.0005	5,000	5.0
Nickel	167	1.16	34	0.09	100	-
Selenium	<2	<0.05	4.0	<0.005	-	0.05
Silver	4.0	<0.005	1.0	<0.007	-	0.1
Thallium	<5	<0.05	-	-	-	-
Vanadium	<4	<0.04	-	-	-	-
Zinc	405	3.04	-	-	250	-
Other Analyses						
Aluminum	-	-	-	-	-	-
Calcium	-	-	-	-	-	-
Cobalt	-	-	-	-	-	-
Iron	-	-	-	-	-	-
Magnesium	-	-	-	-	-	-
Manganese	-	-	-	-	-	-
Potassium	-	-	-	-	-	-
Sodium	-	-	-	-	-	-
Tin	-	-	-	-	-	-
Sulfide	1590	1.2	<11	-	-	-
Total solids	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-
Paint filter test	-	-	-	-	-	-
Diatomaceous earth	-	-	-	-	-	-
Water	690,000	-	580,000	-	500,000	-
Sodium chloride	-	-	-	-	-	-
Chloride	47,000	-	-	-	-	-
Sulfate	19,100	-	-	-	-	-
Total organic carbon	39,600	-	-	-	-	-
Oil and grease	3400	-	22,500	-	-	

- = Not analyzed.

Sources: (a) USEPA 1988c.
(b) Versar 1986.
(c) USEPA 1985.
(d) The Chlorine Institute 1988.

Table 2-4 (continued)

Constituent	Untreated K106 waste concentration					
	(d)		(d)		(d)	
	Total (mg/kg)	TCLP (mg/kg)	Total (mg/kg)	EP Toxicity (mg/kg)	Total (mg/kg)	TCLP (mg/kg)
BDAT List Metals						
Antimony	-	-	-	-	-	-
Arsenic	-	-	-	-	-	-
Barium	-	-	-	-	-	-
Beryllium	-	-	-	-	-	-
Cadmium	-	-	-	-	-	-
Chromium	-	-	-	-	-	-
Copper	-	-	-	-	-	-
Lead	-	-	-	-	-	-
Mercury	28,347	0.399	4098	2.26	23,004	1.25
Nickel	-	-	-	-	-	-
Selenium	-	-	-	-	-	-
Silver	-	-	-	-	-	-
Thallium	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-
Zinc	-	-	-	-	-	-
Other Analyses						
Aluminum	-	-	-	-	-	-
Calcium	-	-	-	-	-	-
Cobalt	-	-	-	-	-	-
Iron	-	-	-	-	-	-
Magnesium	-	-	-	-	-	-
Manganese	-	-	-	-	-	-
Potassium	-	-	-	-	-	-
Sodium	-	-	-	-	-	-
Tin	-	-	-	-	-	-
Sulfide	-	-	-	-	-	-
Total solids	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-
Paint filter test	-	-	-	-	-	-
Diatomaceous earth	-	-	-	-	-	-
Water	290,000	-	-	-	400,000	-
Sodium chloride	-	-	-	-	-	-
Chloride	-	-	-	-	-	-
Sulfate	-	-	-	-	-	-
Total organic carbon	-	-	-	-	-	-
Oil and grease	-	-	-	-	-	

- = Not analyzed.

Sources: (a) USEPA 1988c.
(b) Versar 1986.
(c) USEPA 1985.
(d) The Chlorine Institute 1988.

Table 2-4 (continued)

Constituent	Untreated K106 waste concentration						
	(d)		(d)			(d)	
	Total (mg/kg)	TCLP (mg/kg)	Total (mg/kg)	EP Toxicity (mg/kg)		Total (mg/kg)	TCLP (mg/kg)
BDAT List Metals							
Antimony	-	-	-	-	-	-	-
Arsenic	<100	<0.005	-	<0.1	0.55	0.012	-
Barium	1300	1.32	-	0.12	-	0.07	-
Beryllium	-	-	-	-	-	-	-
Cadmium	<100	<0.01	-	<0.01	6.5	<0.1	-
Chromium	<100	<0.01	-	0.06	2.46	<1	-
Copper	-	-	-	-	-	-	-
Lead	400	0.05	-	<0.1	204	0.5	-
Mercury	10,100	0.113	25,000	0.08	-	<0.1	2,600-32,000
Nickel	-	-	-	-	89	1.0	-
Selenium	<100	<0.005	-	<0.1	90	-	-
Silver	<100	<0.01	-	<0.01	70	<0.3	-
Thallium	-	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-	-
Zinc	-	-	-	-	-	-	-
Other Analyses	-						
Aluminum	-	-	-	-	-	-	-
Calcium	-	-	-	-	-	-	-
Cobalt	-	-	-	-	-	-	-
Iron	-	-	-	-	-	-	-
Magnesium	-	-	-	-	-	-	-
Manganese	-	-	-	-	-	-	-
Potassium	-	-	-	-	-	-	-
Sodium	-	-	-	-	-	-	-
Tin	-	-	-	-	-	-	-
Sulfide	<0.1	-	<0.016	-	-	<1.0	-
Total solids	-	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-	-
Paint filter test	-	-	-	-	-	-	-
Diatomaceous earth	-	-	-	-	-	-	-
Water	650,000	-	-	-	450,000	-	-
Sodium chloride	-	-	-	-	-	-	-
Chloride	-	-	-	-	-	-	-
Sulfate	-	-	-	-	-	-	-
Total organic carbon	-	-	-	-	-	-	-
Oil and grease	-	-	-	-	1270	-	-

- = Not analyzed.

Sources: (a) USEPA 1988c.
(b) Versar 1986.
(c) USEPA 1985.
(d) The Chlorine Institute 1988.
(e) Oxychem 1989. Range of 35 reported values for hydrazine waste.

2.2.2 P065

The Agency does not have data or information on the characterization of P065 wastes. Analysis of the 1986 National Survey of Treatment, Storage, Disposal, and Recycling Facilities (TSDR Survey, USEPA 1986a) and the 1986 National Survey of Hazardous Waste Generators (Generator Survey, USEPA 1986b) data bases indicates that no facilities generated or treated P065 wastes in 1986. As of 1984, the U.S. Army reported that mercury fulminate is no longer used by the U.S. military as an initiating explosive because of poor stability (U.S. Army 1984).

2.2.3 P092

The Agency has no data on the composition of P092 (phenylmercuric acetate) wastes. However, EPA does have data from one manufacturer on the composition of a D009 wastewater generated in production of this chemical. Characterization data for this D009 waste are presented in Table 2-5. EPA expects phenylmercuric acetate to be the primary or sole constituent of P092 wastes.

2.2.4 U151

EPA has data from the Generator Survey on the composition of U151 wastes (USEPA 1986b). These data show that of the U151 wastes that are reported as a single waste code (i.e., not mixed with other listed or characteristic wastes), a majority have mercury concentrations greater than 50 percent. EPA expects that the principal constituent of most U151 wastes is metallic mercury.

2.2.5 D009

Characterization data for D009 wastes generated in the organomercury chemicals and battery manufacturing industries are presented in Table 2-5.

Table 2-5 Waste Composition Data for D009 Wastes

Constituent	Untreated D009 waste concentration (units) (a) Total (mg/l)	(b) Total (mg/kg)	(b) TCLP (mg/l)	(c) Total (mg/kg)	(c) TCLP (mg/l)
BDAT List Metals					
Antimony	-	<2.4	<0.024	<2.4	<0.024
Arsenic	-	<1.0	<0.01	<1.0	<0.01
Barium	-	0.36	0.006	42	1.1
Beryllium	-	<0.1	<0.001	<0.1	<0.001
Cadmium	-	<0.5	<0.005	6.8	0.306
Chromium (total)	-	4.8	<0.004	5.0	<0.004
Copper	-	2.1	0.024	73	0.128
Lead	-	<0.5	0.016	6.6	0.062
Mercury	100-1,000	974,000[a]	1,490	27,200	1.83
Nickel	-	2.8	<0.01	11	0.116
Selenium	-	<0.5	<0.005	<0.5	<0.025
Silver	-	1.1	<0.003	111	0.0047
Thallium	-	<1.0	<0.01	<1.0	<0.01
Vanadium	-	<0.4	<0.004	0.67	<0.004
Zinc	-	<0.3	0.032	29,600	627
BDAT List Organics					
Benzene	50-1,000	-	-	-	-
Toluene	0.01-100		-	-	-
Other Analyses					
Total organic carbon	-	10,700	-	6,620	-

[a]This value is high. The theoretical maximum concentration for pure mercuric oxide (HgO) is 926,000 mg/kg. It is very difficult to analyze such high concentrations of mercury accurately on an instrument designed to detect mercury at ppb levels.

- = Not analyzed

Sources (a) Cosan Chemical Corporation 1989. Waste generated from manufacture of phenylmercuric acetate.
(b) USEPA 1989d. Mercuric oxide waste from recycling of batteries.
(c) USEPA 1989d. Zinc/Mercury amalgam from battery manufacturing.

EPA also has data from the Generator Survey on the composition of D009 wastes (USEPA 1986b). These data show that D009 wastes may contain organic compounds (usually when mixed with solvent wastes). Also, some wastes generated in the production of organomercury compounds for fungicide/bactericide and pharmaceutical uses and generated in organic chemicals and polymers manufacturing where mercuric chloride catalyst is used may contain mercury in an organic waste matrix. Overall, the mercury concentrations of D009 wastes (organic and inorganic) range from less than 1 ppm to greater than 75 percent.

Appendix B lists major mercury compounds, their physical and chemical properties, and, in some cases, industrial uses. Based on the data in Appendix B and data from the Generator Survey, the Agency believes that D009 wastes represent a universe of different wastes.

2.3 Determination of Waste Treatability Groups

EPA has evaluated the characteristics of the K-, P-, D-, and U-code mercury wastes and the processes generating these wastes to determine whether any wastes or groups of wastes can be treated to similar levels using the same technology. If so, these wastes could be classified as a single treatability group.

In some cases, wastes classified under the same waste code may not be treatable to the same concentrations using the same technology or may require different treatment technologies (e.g., wastewater and nonwastewater forms of the same waste). Also, D009 wastes may have the same waste code but they are generated by different processes or by different industries. As a result, D009 wastes can have different waste characteristics, such that the wastes may not be treatable to similar concentrations using the same technology. In these instances, the Agency may subdivide waste codes into several treatability groups.

Alternatively, facilities unable to meet the promulgated standards can petition the Administrator for a variance from the treatment standard. EPA expects the chemical forms of some D-code wastes, in particular, to be different and to clearly require different treatments or combinations of treatments. For example, inorganic and organometallic compounds contain the same metal but may require different types of treatment in order to comply with the treatment standards.

The treatability groups defined by the Agency for the mercury wastes K106, P065, P092, U151, and D009 are discussed in the following subsections. Although D009 wastes can vary, they are not expected to constitute more than one treatability group based on the available information for the physical and chemical properties of major mercury compounds and the operating parameters of BDAT technologies (e.g., temperature, pH, and solubility). Also, this determination is based on the available treatment information for D009 wastes showing that these D009 wastes have treatability characteristics similar to those of one of the mercury wastes identified by EPA as a K, U, or P waste groups. Some subcategories of D009 wastes have thus been combined with the similar K-, U-, or P-code waste or wastes into treatability groups.

2.3.1 Mercury Nonwastewaters

Based on the available waste characterization data, the chemical and physical behavior of mercury compounds upon treatment, and the performance of treatment technologies identified as BDAT, EPA has determined that all mercury nonwastewaters fall into two general treatability groups: (1) the high-mercury treatability subgroup and (2) the low-mercury treatability subgroup. EPA has determined that an exception to these general two subcategories are mercury wastes also showing radioactive characteristics.

EPA lacks data to define the nature and characteristics of all wastes in these groups. However, the available data indicate that most mercury

nonwastewaters currently being retorted/roasted contain inorganic mercury. These same data indicate that nonwastewater wastes derived from the treatment of organomercury wastes can also be retorted. Other mercury wastes, however, such as mercury fulminate (P065), may require pretreatment, such as incineration or chemical treatment, to convert the wastes to a form more amenable to recovery/recycling.

In the absence of other characterization data that can further define those nonwastewaters amenable to retorting/roasting, EPA is relying on characterization data from untreated mercury wastes being retorted/roasted to establish 260 mg/kg as a cutoff level to define the high- and low-mercury treatability groups. Derivation of this cutoff level is discussed in Section 7.2. Inorganic and organic mercury nonwastewater members of these two treatability groups are discussed below.

(1) Inorganic mercury nonwastewaters. EPA has identified certain wastes as inorganic mercury nonwastewaters. These wastes are expected to contain mercury in the metallic form or as inorganic mercury compounds and are not expected to contain significant concentrations of organic compounds. These wastes include waste codes K106, U151, and many D009 wastes. Mercury fulminate (P065) dissociates in water to mercury ions and cyanate ions and therefore is chemically more similar to inorganic mercury compounds than to organomercury compounds. P065 and other reactive mercury wastes will, however, be discussed with the organic mercury wastes because they can be treated by similar technologies such as incineration.

Inorganic mercury nonwastewaters (K106, U151, and D009 wastes) are amenable to mercury recovery technologies because the mercury is present in the elemental form or as inorganic mercury compounds. Domestically, inorganic mercury nonwastewaters with untreated mercury concentrations starting at 255 mg/kg have been demonstrated to be retorted. EPA had data indicating that in foreign countries wastes with mercury levels as

low as 10 mg/kg have been demonstrated to be retorted. In addition, data from thermal processing of cinnabar ore indicate that mercury sulfide compounds can be retorted/roasted for mercury recovery.

Based on the available information and for the purpose of this rule, EPA has determined that nonwastewater forms of mercury wastes having concentrations of mercury above 260 mg/kg can be retorted/roasting. Hence, EPA has divided these wastes into two treatability groups: the high-mercury treatability group and the low-mercury treatability group. This reflects the applicability of mercury recovery technologies to only mercury nonwastewaters containing recoverable concentrations of mercury.

K106 wastes, as generated, contain from 0.5 percent to 16 percent mercury, normally (except for one known generator) in the form of mercuric sulfide (see Table 2-4). Sulfide-containing residuals from wastewater treatment not listed as K106 may also be classified as D009 wastes or (by the "derived-from" rule) as U151, P065, or P092.

Mercuric sulfide has the highest decomposition temperature of any of the common mercury compounds (Weast 1977). Because decomposition is the first step in the volatilization of mercury compounds in mercury recovery, these wastes are expected to be the most difficult from which to recover mercury.

Other inorganic wastes contain mercury either in the elemental form or as nonsulfide compounds. These wastes are expected to be more easily treatable by mercury recovery technologies than are the mercuric sulfide wastes.

K106 nonwastewaters are generated at one mercury cell chloralkali facility by treatment of wastewaters using hydrazine as a reducing agent to precipitate mercury as mercuric hydroxide and metallic mercury. The sludges generated from filtration of this wastewater would be expected to contain mercury and mercury oxide or hydroxide compounds.

U151 nonwastewaters and some D009 nonwastewaters also contain elemental mercury or inorganic mercury compounds as the primary constituent. The Agency's data on the composition of U151 wastes (summarized in Section 2.2.4) indicate that the majority of these wastes, when not mixed with other wastes, are composed of greater than 50 percent mercury. D009 wastes containing mercury or nonsulfide inorganic mercury compounds as the major constituent would also be expected to be treatable to similar levels as U151 wastes and nonsulfide K106 wastes using the same technologies.

(2) Organic mercury nonwastewaters. These wastes comprise P065 nonwastewaters and P092 nonwastewaters, as well as some D009 nonwastewaters. The Agency expects some D009 nonwastewaters to contain organomercury compounds or mercury in an organic waste matrix. These wastes may be generated from paint formulation, from the manufacture of organomercury pharmaceuticals, and from the use of homogeneous mercury catalysts in the production of organic chemicals. Because of the presence of organomercury compounds (such as phenylmercuric acetate) or organic compounds in the waste, these wastes may require pretreatment (such as incineration) prior to being treated by the same technologies as D009 nonwastewaters containing only inorganic mercury compounds.

P065 wastes and D009 wastes containing explosive mercury compounds may require specially-designed incinerators for treatment. EPA has no data on the composition of P065 wastes, but expects mercury fulminate to be the major constituent. Mercury fulminate and mercury azide, both extremely explosive compounds used as explosive initiators, may also be the major constituent of some D009 wastes. The Agency expects that both nonwastewater and wastewater forms of these wastes will be treatable to similar levels as other inorganic nonwastewaters and wastewaters after treatment of these wastes to remove the reactivity hazard.

2.3.2 Radioactive Wastes Containing Mercury

Information provided to EPA by the United States Department of Energy (DOE) indicates the generation of two mixed radioactive/hazardous wastes that contain mercury. Treatment technologies applicable to other mercury-containing nonwastewaters may not be applicable to treatment of these wastes. The Agency, therefore, has established two separate treatability groups for radioactive wastes containing mercury, which are discussed below.

In the nuclear industry, elemental mercury found in vacuum pumps, manometers, and other instruments may be contaminated with radioactive tritium (a radioisotype of hydrogen). These wastes are often identified as D009 or U151. The Agency has no data or information indicating that recovery processes applicable to treatment of other inorganic mercury nonwastewaters would be able to separate the mercury from the radioactive material and recover reusable mercury. These wastes thus represent a separate treatability group from other inorganic high-mercury nonwastewaters.

The DOE also indicated the generation of a hydraulic oil contaminated with mercury and tritium. This waste is expected to be similar to the organic mercury nonwastewaters identified in Section 2.3.1 above in that the organic components of the waste would have to be treated before the mercury could be treated effectively. Treatment of this waste may be different from treatment of the other organic nonwastewaters, however, because recovery technologies may not be applicable for treatment of the nonwastewater residuals generated from incineration since reusable (i.e., nonradioactive) mercury may not be recoverable from these residuals. Radioactive hydraulic oils containing mercury thus represent a separate treatability group from other organic mercury nonwastewaters.

2.3.3 Wastewaters

EPA has determined that K106, U151, P065, and P092 wastewaters represent a single treatability group. K106 wastewaters are generated from treatment of K106 wastes (e.g., as scrubber waters from thermal treatment methods). EPA has no data on the composition of K106, U151, or D009 wastewaters. However, the Agency expects K106 wastewaters to contain only the major constituents, which are mercury and non-BDAT list inorganics, reported for K106 wastes as generated (as shown in Table 2-4). EPA expects K106 and U151 wastewaters to contain suspended or dissolved metallic mercury or soluble inorganic mercury compounds (e.g., mercuric chloride). EPA has no data on P092 wastewaters, but expects these wastes to contain phenylmercuric acetate, a soluble organomercury compound, as a major constituent.

D009 wastewaters containing suspended or dissolved metallic mercury or soluble inorganic mercury compounds are expected to be amenable to treatment by the same technologies as are applicable for treatment of K106 wastewaters. As discussed in Section 2.1.3, EPA also expects D009 wastes generated from the paint formulation industry to contain phenylmercury compounds in an organic or inorganic waste matrix. Other D009 wastes, as generated, may be mixed with solvent constituents (USEPA 1986b). These wastewaters may require other treatment trains (e.g., chemical oxidation with reagents such as hypochlorite or hydrogen peroxide) in order to treat organics that may interfere with the treatment of mercury. However, EPA currently lacks information to indicate that these wastes cannot be treated to levels similar to those achieved for inorganic mercury wastewaters.

3. APPLICABLE AND DEMONSTRATED TREATMENT TECHNOLOGIES

In the previous section, discussions of the industries and processes generating mercury-containing wastes and major constituent analyses of these wastes were presented. Treatability groups were identified for the mercury-containing wastes. This section describes the applicable and demonstrated treatment technologies for each mercury treatability subgroup. The technologies that are considered applicable to the treatment of mercury-containing wastes are technologies that treat BDAT list metals by reducing their concentration and/or their leachability in the waste and technologies that treat the organic compounds or organomercury compounds found in these wastes (so that the mercury left behind can subsequently be treated). Detailed discussions of these treatment technologies can be found in EPA's Treatment Technology Background Document (USEPA 1989b).

3.1 Applicable Treatment Technologies

Based on the waste characteristics discussed in the previous section, the technologies applicable for treatment of mercury-containing wastes are those that reduce the concentration of BDAT list metals and/or reduce the leachability of these metals leaving behind a treated residual acceptable for land disposal. Because organic mercury wastes (P092 wastes and some forms of D009 wastes) may contain organic mercury compounds or mercury compounds in an organic waste matrix, treatment technologies that are applicable to these wastes must also be able to free the mercury from its organic bond so that subsequent mercury treatment is effective. P065 and some D009 wastes contain carbon-mercury compounds that show reactive characteristics, and these compounds must be treated for those reactive characteristics prior to treatment to recover mercury.

3.1.1 Applicable Technologies for Nonwastewaters

The Agency has identified thermal mercury recovery processes, the acid leaching process, and stabilization as applicable for treatment of nonwastewaters containing metallic mercury and/or inorganic mercury compounds. Incineration and chemical oxidation have been identified as applicable for treatment of nonwastewaters containing organomercury compounds or mercury in an organic waste matrix. Aqueous chemical deactivation and incineration in units specially designed for treatment of explosive wastes have been identified as applicable treatment technologies for treatment of reactive mercury-containing nonwastewaters. Absorption technologies have been identified as applicable for treatment of spilled metallic mercury wastes.

(1) Thermal mercury recovery processes. Thermal mercury recovery processes volatilize mercury from the waste at high temperatures and then condense and collect it as the pure metal, reducing the mercury concentration in the treatment residual compared to that in the untreated waste. Thermal recovery processes for mercury include retorting, roasting, distillation processes (vacuum distillation or batch steam distillation), and thermal processes recovering mercury from concentrated mercury ores.

Retorting and roasting processes can be operated as batch processes in a closed vessel or continuously in a furnace. In retorting processes, waste is heated and mercury vaporizes and is collected in a condenser. The vessel is usually kept either at a slightly negative pressure or under a strong vacuum. Air is not introduced from outside the vessel. Roasting processes are usually operated continuously, but may be operated in batch. In roasting, air is supplied to the system as a source of oxygen to enable decomposition of some mercury compounds. Retorting and high-temperature metals recovery technologies are discussed further in the Treatment Technology Background Document (USEPA 1989b).

Distillation technologies are applicable to treatment of wastes containing high concentrations of metallic mercury (such as U151). The residuals from distillation technologies are a high-purity mercury as the "overhead" product and the remaining solid residual as the "bottoms." Distillation processes are also discussed in the Treatment Technology Background Document (USEPA 1989b).

The thermal process used to recover mercury from concentrated mercury ores is very similar to continuous retorting. These two thermal processes used to recover mercury take place in a multiple hearth furnace followed by condensation of volatilized mercury. All four thermal mercury recovery processes discussed above may generate a wastewater from air pollution control equipment that may contain mercury.

(2) Acid leaching process. Acid leaching solubilizes low concentrations of mercury in wastes, reducing the concentration of mercury in the nonwastewater treatment residual. The acid leaching process used for treatment of K071 wastes involves a chemical oxidation step followed by a step combining sludge dewatering and acid washing. This process generates an acid leachate (wastewater) that contains the mercury in soluble ionic form and requires treatment by chemical precipitation. Acid leaching is described in the Treatment Technology Background Document (USEPA 1989b).

(3) Stabilization. Stabilization is applicable for treatment of nonwastewaters containing BDAT list metals in an inorganic waste matrix. Stabilization treatment involves mixing the waste with a binding agent that is designed to reduce the leachability of metals from the waste. Common stabilization technologies are discussed in detail in the Treatment Technology Background Document (USEPA 1989b).

(4) Incineration. Incineration is applicable to treatment of wastes containing organic and organometallic constituents. Treatment using incineration technologies will destroy the organic constituents of the waste. As a consequence of destruction of the organics, incineration will break the organic-metal bond in the organometallic waste constituents. The metallic part of the organometallic constituents in the waste, as well as any metals present in a mixed metal/organic waste, will remain in the residual (ash) generated, will be removed from the gases exiting the incinerator by the air pollution control equipment, or will remain in the gases exiting the incineration system. Incineration technologies are described in the Treatment Technology Background Document (USEPA 1989b).

(5) Chemical oxidation of organomercury compounds. Chemical oxidation is applicable to the treatment of wastes containing organomercury constituents (such as phenylmercuric acetate, P092). Chemical oxidation treatment of organomercury compounds involves addition of a chemical oxidizing agent such as chlorine, hypochlorite, permanganate, or ozone in an aqueous reaction medium. Chemical oxidation results in the breaking of the organic-mercury chemical bond, thereby generating a residual from which the organic contaminant can either be destroyed (by further oxidation or incineration) or recovered (by distillation). Chemical oxidation is discussed in the Treatment Technology Background Document (USEPA 1989b). The inorganic mercury wastewaters resulting from chemical oxidation treatment can be treated by one of the technologies identified in Section 3.1.2 as applicable for wastewaters containing inorganic mercury compounds.

(6) Aqueous chemical deactivation. Aqueous chemical deactivation is applicable for treatment of wastes containing reactive mercury constituents (such as mercury fulminate, P065). Aqueous chemical deactivation involves careful dissolution of explosive solids in water,

combined with oxidation treatment of the dissolved waste. In the case of mercury fulminate (mercuric cyanate), the dissolved cyanate ions can be chemically oxidized completely to carbon dioxide and nitrogen using strong aqueous oxidizing agents such as sodium hypochlorite. The chemical reaction of mercury fulminate with sodium thiosulfate ($Na_2S_2O_3$), recommended by the Army as the proper chemical deactivating agent (U.S. Army 1984), forms thiocyanate as follows:

$$Hg(OCN)_2 + 2Na_2S_2O_3 \rightarrow HgSO_4 + Na_2SO_4 + 2NaSCN$$

(7) Absorption of elemental mercury. Several methods have been developed to handle spills of liquid metallic mercury. These methods involve absorption of mercury with several agents. Calcium polysulfide and flowers of sulfur are the most common mercury absorbents used, and elemental zinc powder is also used.

Because of the high vapor pressure associated with elemental mercury in the liquid form (compared to other metals), the predominant safety concern with elemental mercury wastes is air emissions. In absorption of liquid mercury with zinc dust, elemental zinc powder is applied to areas that have been contaminated with mercury. The visible droplets of liquid mercury are physically collected in a separate step before application of the zinc. The zinc is dampened with dilute sulfuric acid (5 to 10 percent) until a paste is formed. This paste is then collected for disposal. The mercury forms an amalgam with the zinc, providing a significant reduction in air emissions of mercury (Easton 1988). EPA prefers this procedure over the conventional spill cleanup procedures involving addition of calcium polysulfide or flowers of sulfur because use of zinc results in lower air emissions of mercury.

3.1.2 Applicable Technologies for Wastewaters

(1) Chemical precipitation and chemical reduction. EPA has identified chemical precipitation and chemical reduction, both followed by filtration, as applicable to treatment of mercury-containing wastewaters with high concentrations of inorganic mercury compounds. Chemical precipitation followed by filtration removes BDAT list metals and concentrates them in the wastewater treatment sludge. Chemical reduction (with reagents such as sodium borohydride) reduces mercury to the metallic state. The reduction step is then followed by filtration to remove mercury and other solids.

The applicability of chemical precipitation and chemical reduction technologies depends to some extent on the form of mercury in the waste (e.g., dissolved ionic, pure metal, and insoluble ionic). Mercury in the dissolved ionic form (soluble mercuric compounds, for example) may be reduced to the pure metal by the borohydride reduction process, while this process may not be effective in treatment of the insoluble mercury compounds. The borohydride process cannot remove the small amount of metallic mercury that is soluble in water. Chemical oxidation treatment may be required to oxidize metallic mercury to soluble ionic mercury prior to chemical precipitation treatment. Chemical precipitation, chemical reduction, and chemical oxidation technologies are discussed in the Treatment Technology Background Document (USEPA 1989b). The solids produced as a residual from chemical reduction processes are, in general, easier to treat by high-temperature metals recovery methods than are the solids produced in chemical precipitation treatment because they contain mercury in its elemental form rather than as mercuric salts.

(2) Chemical oxidation of organomercury constituents. EPA has identified chemical oxidation followed by chemical precipitation and filtration as an applicable technology for wastewaters containing

organomercury constituents. Chemical oxidation breaks the bonds between the mercury and the organic components of these constituents, as discussed in Section 3.1.1(5). Chemical precipitation then treats the mercury in the inorganic form.

(3) Carbon adsorption and ion exchange. Two other technologies, carbon adsorption and ion exchange, are also applicable to treatment of wastewaters containing relatively low concentrations of dissolved mercury. The mercury must be in the soluble mercuric (Hg^{+2}) form in order to be removed by these technologies (Rosenzweig 1975, Iammartino 1975). Thus, these technologies may require pretreatment by chemical oxidation to solubilize any insoluble inorganic mercury. Carbon adsorption will also remove mercury from wastes containing dissolved organomercury compounds.

Carbon adsorption and ion exchange produce both a wastewater residual (from regeneration of the ion exchange resin or activated carbon bed) and a nonwastewater residual (the spent carbon or ion exchange resin, when these are exhausted and must be discarded). The waste regenerant solutions (usually acid solutions) are more concentrated than the original waste treated and must usually be treated for mercury removal by chemical precipitation followed by filtration if these regenerant solutions are not recyclable to the process originally generating the waste. Spent carbon can be incinerated (if mercury emissions are controlled) or processed in a retort to recover residual mercury. The spent resins may also be processed by retorting to recover residual mercury. Carbon adsorption and ion exchange technologies are discussed in the Treatment Technology Background Document (USEPA 1989b).

3.2 Demonstrated Treatment Technologies

Section 3.1 described applicable technologies for treatment of mercury wastes. This section identifies, for nonwastewaters and

wastewaters, those applicable technologies that are demonstrated in terms of the waste treatability groups that were discussed in Section 2.3. To be demonstrated, a technology must be in full-scale use to treat either the waste in question or a similar material.

3.2.1 Demonstrated Technologies for Nonwastewaters

Retorting, roasting, batch distillation technologies, and thermal treatment of mercury ores are all demonstrated for treatment of nonwastewaters containing mercury as the metal or as inorganic mercury compounds. Another demonstrated technology to treat mercury wastes (soluble inorganic mercury) is acid leaching. During the comment period for the proposed rule, EPA received numerous comments disputing EPA's determination that retorting/roasting has been demonstrated for mercury-containing nonwastewaters. These comments are addressed in Section 5.1.1.

Incineration has been identified as demonstrated for treatment of nonwastewaters containing organomercury constituents or containing inorganic mercury in an organic waste matrix. EPA received comments during the comment period for the proposed rule indicating that direct retorting/roasting of organomercury wastes is demonstrated and practical. Also, EPA has information for an oxidation-retorting patented process demonstrated for organomercury wastes. EPA has information that this process is also demonstrated for inorganic mercury wastes. This oxidation-retorting process is deemed as retorting by EPA for the purpose of this rule. Incineration in specially-designed units has been identified as demonstrated for explosive mercury nonwastewaters.

Retorting was used in the past to treat K106 at two mercury cell chloralkali facilities. Also, retorting was used to treat a mixture of K071 and K106 at another facility. EPA is not aware of any facilities

currently retorting K106 sulfide wastes. However, a thermal treatment process similar to retorting is presently being used at one facility for recovery of mercury from ores consisting primarily of mercuric sulfide (cinnabar) (K106 also ordinarily contains primarily mercury sulfide). These ores are concentrated to approximately 70 to 75 percent mercury prior to retorting (from 3 percent in the unprocessed ores). As shown in Table 2-4, the concentration of mercury in nonwastewater K106 generated by sulfide treatment averages 4.4 percent, and the concentration of mercury in K106 generated by hydrazine treatment is 0.5 percent. The processed mercury ores are much more concentrated in mercury (as mercury sulfide) than either form of K106. Hence, the Agency believes that the mercury ores are much more difficult to treat than K106. As a consequence, the Agency considers retorting to be demonstrated for K106 and other sulfide-containing nonwastewaters.

Retorting is also demonstrated at two additional facilities for treatment of nonsulfide-containing mercury nonwastewaters. U151 wastes and inorganic D009 wastes such as mercury lamps, debris, contaminated equipment, and mercury cell batteries are routinely treated by retorting, vacuum or scrap metal distillation, and a thermal proprietary process.

Incineration is demonstrated for many RCRA-listed hazardous wastes that contain BDAT list metals (such as K048-K052 and K087). EPA believes incineration is currently used for treatment of organomercury wastes such as spent mercury catalysts from organic chemicals production, paint sludges, or organomercury lab packs. Incineration in specially-designed units has been identified as a demonstrated technology for many D001 reactive wastes (USEPA 1989e), including some wastes that contain metals as well as organics. The U.S. Army recommends this technology for treatment of mercury fulminate (P065) wastes (U.S. Army 1984).

Application of elemental zinc powder to form a zinc-mercury amalgam is a common demonstrated method of cleanup of spilled mercury (Easton 1988). This technology is expected to provide some treatment for radioactive metallic mercury wastes, for which mercury recovery technologies may not be applicable.

Acid leaching is demonstrated at chloralkali facilities generating K071 wastes. K071 wastes contain soluble mercuric chloride, insoluble mercuric oxide, and elemental mercury (USEPA 1988b). This technology requires an additional step of oxidation to convert insoluble forms of mercury to the mercuric (+2) form, which is soluble. The soluble mercuric form can then be precipitated as sulfide salt. Several commenters submitted comments supporting the demonstrability of this technology but noting that it may not be suitable for "elemental mercury and mercury oxides." However, these commenters failed to submit data supporting these claims of limitations in the applicability of acid leaching technologies. Based on the K071 data, EPA believes this technology is demonstrated for most mercury compounds listed in Appendix B that show solubility ranges similar to those of the mercury compounds identified in K071 wastes.

Stabilization was identified as potentially applicable for treatment of K106 nonwastewaters and possibly certain D009 nonwastewaters. Stabilization typically binds BDAT list metals into a solid in a form that is more resistant to leaching than the metals in the untreated waste. EPA's testing of cement, kiln dust, and lime/fly ash stabilization for treatment of K106 nonwastewaters generated by sulfide precipitation indicates that the technology did not provide effective treatment. EPA believes the ineffectiveness of stabilization treatment of K106 in this EPA test may have resulted from the mercury sulfide behavior in alkaline media. Similarly, industry submitted data on stabilization of "D009 soil/debris" and unspecified D009 or K071 waste, but these data show untreated and treated waste TCLP concentrations below the toxic characteristic level (HWTC 1989a,b; Chemfix 1989) for D009 wastes.

Based on the available data, EPA has concluded that stabilization with alkaline materials may not be demonstrated for K106 wastes containing high concentrations of mercury sulfide. The stabilization data collected by EPA are summarized in Section 4.1. It is possible that stabilization may be applicable for treatment of other mercury containing wastes if mercury is present in a more leachable form (e.g., a nonsulfide form) or is present at low concentrations in the untreated waste (based on the data received during the comment period for this rule; see Table 4-8). Other stabilizing agents, such as proprietary asphalt or silicate agents, may also be applicable, but data to enable such a determination have not been provided to EPA.

3.2.2 Demonstrated Technologies for Wastewaters

Chemical precipitation followed by filtration has been demonstrated for treatment of K071 wastewaters. EPA does not have characterization data on K106 wastewaters generated from retorting of K106. However, EPA does have data on wastewaters generated from air pollution control devices from the thermal processing of mercuric sulfide ores to recover metallic mercury. The Agency believes that these wastewaters (K106 wastewaters and wastewaters produced from mercuric sulfide ore processing) are similar to the K071 and other mercury-contaminated wastewaters currently treated by chemical precipitation (see Table 4-7) because they are expected to contain mercury as the major BDAT list constituent and are not expected to contain concentrations of organic compounds that would affect treatment by chemical precipitation. The mercury compounds expected to be found in wastewaters from processing K106 wastes should be easier to treat than those present in K071 wastewaters. K071 wastewater contains soluble mercury, mercury compounds such as mercury chloride (produced from acid leaching of K071 nonwastewaters). K106 (and also mercury sulfide ore processing) wastewaters are, in large part, scrubber waters in which mercury is

expected to be present in metallic or oxide form, since it is metallic mercury that vaporizes from the retorter or roaster. Metallic mercury and oxides of mercury are essentially insoluble and may only require treatment by coagulation and settling, while the mercury chlorides in K071 require chemical precipitation (e.g., with sulfide) in addition to coagulation and settling. The concentration of mercury in the wastewaters for which the Agency has treatment data ranges from 9.25 to 77.2 mg/l. The ore roasting air pollution control wastewaters contained a maximum mercury concentration of 8.52 mg/l (see Table 4-1). EPA would not expect the K106 wastewaters generated from retorting to be more difficult to treat than the waste tested by the Agency because they are expected to have concentrations of mercury similar to that of the ore roasting air pollution control wastewaters generated in EPA testing of mercuric sulfide ore roasting. Chemical precipitation followed by filtration of mercury-containing wastewaters is demonstrated and practiced at 19 or more facilities.

Ion exchange is demonstrated at many facilities in Europe for treatment of wastewaters generated from the mercury cell chloralkali process. Activated carbon adsorption is also used at several facilities for treatment of inorganic/organo mercury-containing wastewaters (Rosenzweig 1975).

Therefore, the Agency believes that chemical precipitation, ion exchange, and carbon adsorption are all applicable and demonstrated for treatment of wastewaters generated from thermal treatment of K106 wastewaters and for treatment of wastewaters generated from the management of other mercury-containing treatment sludge wastes.

Chemical oxidation technologies are also demonstrated for treatment of wastewaters containing oxidizable inorganic constituents (such as cyanide or cyanate) (USEPA 1989f).

As discussed in Section 3.2.1, incineration in specially-designed units is demonstrated for explosive mercury nonwastewaters. This technology, as well as aqueous chemical deactivation by chemical oxidation, is also recommended by the Army for treatment of mercury fulminate wastewaters. Chemical oxidation is also demonstrated for many wastewaters containing organics or oxidizable inorganics (such as cyanate).

4. PERFORMANCE DATA

4.1 Performance Data for Nonwastewaters

For treatment of inorganic mercury-containing nonwastewaters, EPA has treatment performance data as described below. EPA collected five sets of treatment data from a thermal mercury recovery system that processes mercuric sulfide ores for mercury recovery. These data, presented in Table 4-1 (at the end of this section), show total composition, TCLP, and EP leachate data for both the untreated mercury ores and the treated nonwastewater furnace residue and also include data for the wastewaters generated from the air pollution control devices (APCDs). Table 4-2 presents total composition, TCLP, and EP leachate data for two samples of dust collected from the dust cyclone component of the APCD. Also presented are design and operating data associated with each sample set.

Plant B submitted four sets of performance data for retorting treatment of K106 hydrazine sludge, presented in Table 4-3. These data include total and EP leachate concentration of mercury in the untreated waste and data for mercury and the other EP metals in the treated nonwastewater residual, as well as design and operating data associated with each sample set. Table 4-4 also presents performance data for retorting of K106 hydrazine sludge. Total mercury concentration in the untreated waste and total mercury and EP leachate concentrations for the treated waste are provided for 35 sets of data.

Table 4-5 presents two sets of performance data on retorting treatment of a combined K071/K106 waste. These data show total mercury concentration for each test in the untreated waste and a range of total mercury concentrations for the treated nonwastewater residual, as well as design and operating data for each sample set. No leachate concentration data were generated for untreated or treated wastes.

Plant C submitted seven sets of performance data for retorting of a K106 sludge generated by sodium borohydride reduction and filtration. These data, presented in Table 4-6, show total mercury concentration of the untreated waste and total and EP leachate mercury concentrations for the treated nonwastewater residual. No design or operating data were included.

Oxychem (1989, 1990) provided total mercury concentration data for residuals from retorting of D009 mercury cell room trench sludge. Twelve data points for retorted D009 wastes were submitted describing mercury concentrations ranging from 32 to 2,042 mg/kg. No data were generated on the untreated wastes prior to retorting, nor was any EP toxicity or TCLP testing performed on the treated residuals.

Table 4-7 presents data collected by EPA on stabilization of K106 wastes. These data show the total and TCLP BDAT list metal concentrations for the untreated waste and the TCLP concentration for the treated waste. Three binding agents (lime/fly ash, kiln dust, and cement) were tested. The table presents the results of the test for kiln dust, which was the most successful of the three binding agents in terms of reduction of the TCLP leachate concentration for mercury. Note the results for sample set No. 2 show a significant increase in mercury TCLP leachate concentration in the treated waste compared to that in the untreated waste.

Table 4-8 presents industry-submitted data on stabilization of "D009 contaminated soil and debris from the natural gas pipeline industry" (HWTC 1989a,b). The wastes were stabilized using undisclosed, proprietary reagents. Data were submitted for total mercury content of the untreated wastes and TCLP of the treated waste for four sample sets. Untreated waste TCLP concentrations were reported for only two of the sample sets. Both the untreated and treated TCLP results are less than

the toxic characteristic level for mercury. One of the treated waste TCLP values was greater than the untreated value. Because of the small size of this data set and the low untreated waste concentrations involved, EPA does not believe a performance evaluation would be meaningful. Treatment data submitted by Chemfix for unspecified D009 wastes and possibly a K071 waste were too incomplete (no QA/QC data or design and operating data were provided) to enable any performance evaluation to be made (Chemfix 1989). EPA requested additional information from Chemfix, but this commercial vendor has not yet provided the requested information.

Data were presented in the BDAT background document for K071 (USEPA 1988b) on acid leaching treatment of K071 wastes. These data included both EPA-collected data and data submitted by industry.

4.2 Performance Data for Wastewaters

The Agency collected three data sets of untreated and treated data for treatment of K071 wastewater in a sulfide precipitation and filtration treatment system. The treatment performance data for K071 wastewaters are presented in Table 4-9.

EPA does not have analytical data on wastewaters as generated from retorting operations. EPA believes that these wastewaters would be similar in chemical and physical characteristics to wastewaters generated in treatment of K071 waste by acid leaching and other mercury-containing wastewaters.

The Agency does have data characterizing the wastewater generated from air pollution control at the facility at which mercuric sulfide ores were processed. These wastewaters contained up to 8.4 mg/l mercury and are similar in composition to K071 wastewaters.

Table 4-1 Ore Roasting Performance Data from Thermal Recovery of Mercuric Sulfide Ores Collected by EPA at Plant A

Sample Set No. 1

Constituent	Untreated waste Total (mg/kg)	Untreated waste TCLP (mg/l)	Untreated waste EP leachate (mg/l)	Treated nonwastewater Total (mg/kg)	Treated nonwastewater TCLP (mg/l)	Treated nonwastewater EP leachate (mg/l)	Air pollution control wastewater Total (mg/l)
Antimony	330	0.82	-	1,170	0.47	-	3.23
Arsenic	290	0.41	0.33	960	7.3	4.54	0.023
Barium	13	0.69	0.19	77	0.21	0.14	0.007
Beryllium	0.15	<0.001	-	0.39	0.0013	-	<0.002
Cadmium	3.4	<0.005	0.007	5.0	0.051	0.037	<0.004
Chromium (total)	2.8	<0.003	0.009	5.2	<0.003	<0.003	<0.007
Copper	8.2	0.012	-	23	<0.003	-	<0.003
Lead	3.1	<0.05	<0.028	5.8	<0.005	<0.028	0.011
Mercury	625,000	0.26	0.10	45	<0.0002	<0.0002	3.25
Nickel	<1.0	<0.01	-	2.0	<0.01	-	<0.013
Selenium	3.6	<0.005	<0.005	<0.5	<0.05	<0.05	<0.005
Silver	2.8	<0.004	<0.004	7.6	<0.004	<0.004	<0.003
Thallium	6.2	0.03	-	<1.0	<0.01	-	0.013
Vanadium	5.4	<0.003	-	27	0.012	-	<0.003
Zinc	50	0.33	-	94	0.17	-	0.026

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Temperature of #2 furnace hearth (°F)	1350-1450	1500-1530
Temperature of #4 furnace hearth (°F)	1450-1550	1580
Ore concentrate feed rate (lb/hr)	1000-1300	1370

- = Not analyzed

Source: USEPA 1989g.

Table 4-1 (continued)

Sample Set No. 2

Constituent	Untreated waste Total (mg/kg)	Untreated waste TCLP (mg/l)	Untreated waste EP leachate (mg/l)	Treated nonwastewater Total (mg/kg)	Treated nonwastewater TCLP (mg/l)	Treated nonwastewater EP leachate (mg/l)	Air pollution control wastewater Total (mg/l)
Antimony	360	0.79	-	2,270	4.1	-	5.76
Arsenic	280	0.44	0.33	1,290	18.7	10.6	0.032
Barium	12	0.72	0.14	66	0.18	0.21	0.011
Beryllium	0.13	<0.001	-	0.43	<0.001	-	<0.002
Cadmium	2.7	0.006	<0.005	7.4	0.15	0.095	<0.004
Chromium (total)	3.1	0.004	<0.003	5.8	<0.003	<0.003	<0.007
Copper	8.4	0.013	-	26	<0.003	-	<0.003
Lead	3.2	<0.005	<0.028	10	<0.005	<0.028	0.017
Mercury	738,000	0.42	0.087	42.4	0.00047	<0.0002	8.52
Nickel	<1.0	<0.01	-	3.5	<0.01	-	<0.013
Selenium	2.8	<0.005	<0.005	<0.5	<0.05	<0.05	<0.005
Silver	2.6	<0.004	<0.004	8.6	<0.004	<0.004	<0.003
Thallium	5.6	0.03	-	<1.0	<0.01	-	0.029
Vanadium	5.1	<0.003	-	24	0.021	-	<0.003
Zinc	49	0.34	-	120	0.26	-	0.042

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Temperature of #2 furnace hearth (°F)	1350-1450	1440-1510
Temperature of #4 furnace hearth (°F)	1450-1550	1540-1580
Ore concentrate feed rate (lb/hr)	1000-1300	1370

- = Not analyzed
Source: USEPA 1989g.

Table 4-1 (continued)

Sample Set No. 3

Constituent	Untreated waste Total (mg/kg)	Untreated waste TCLP (mg/l)	Untreated waste EP leachate (mg/l)	Treated nonwastewater Total (mg/kg)	Treated nonwastewater TCLP (mg/l)	Treated nonwastewater EP leachate (mg/l)	Air pollution control wastewater Total (mg/l)
Antimony	320	0.82	-	1,920	0.94	-	2.73
Arsenic	270	0.44	0.36	1,220	12	1.1	0.029
Barium	12	1.03	0.13	70	0.18	0.13	0.010
Beryllium	0.12	<0.001	-	0.45	<0.001	-	<0.002
Cadmium	2.8	0.008	0.008	7.1	0.091	0.014	<0.004
Chromium (total)	3.5	0.006	<0.003	5.6	<0.003	<0.003	<0.007
Copper	9.0	0.014	-	32	<0.003	-	<0.003
Lead	3.0	<0.005	<0.028	7.0	<0.005	<0.028	0.013
Mercury	640,000	1.44	0.078	36	<0.0002	<0.0002	4.14
Nickel	1.2	<0.01	-	3.6	<0.01	-	<0.013
Selenium	5.5	<0.005	<0.005	<0.5	<0.05	<0.05	<0.005
Silver	3.5	<0.004	<0.004	10	<0.004	<0.004	<0.003
Thallium	5.1	0.031	-	<1.0	<0.01	-	0.027
Vanadium	5.2	<0.003	-	30	<0.003	-	<0.003
Zinc	52	0.64	-	140	0.073	-	0.032

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Temperature of #2 furnace hearth (°F)	1350-1450	1480
Temperature of #4 furnace hearth (°F)	1450-1550	1570
Ore concentrate feed rate (lb/hr)	1000-1300	1370

- = Not analyzed
Source: USEPA 1989g.

Table 4-1 (continued)

Sample Set No. 4

Constituent	Untreated waste Total (mg/kg)	Untreated waste TCLP (mg/l)	Untreated waste EP leachate (mg/l)	Treated nonwastewater Total (mg/kg)	Treated nonwastewater TCLP (mg/l)	Treated nonwastewater EP leachate (mg/l)	Air pollution control wastewater Total (mg/l)
Antimony	350	0.84	-	2,200	0.05	-	5.13
Arsenic	300	0.42	0.36	1,590	7.6	3.8	0.041
Barium	14	0.77	0.14	66	0.14	0.13	0.010
Beryllium	0.16	<0.001	-	0.43	0.00014	-	<0.002
Cadmium	3.3	0.006	<0.005	9.6	0.061	0.03	<0.004
Chromium (total)	3.7	0.006	<0.003	6.4	<0.003	<0.003	<0.007
Copper	9.0	0.010	-	28	<0.003	-	<0.003
Lead	3.3	0.006	<0.028	15	<0.005	<0.028	0.019
Mercury	473,000	3.8	0.093	23	<0.0002	<0.0002	7.26
Nickel	1.0	<0.01	-	4.6	<0.01	-	<0.013
Selenium	1.2	<0.005	<0.005	<0.5	<0.05	<0.05	0.012
Silver	3.2	<0.004	<0.004	9.6	<0.004	<0.004	<0.003
Thallium	5.1	0.037	-	<1.0	<0.01	-	0.041
Vanadium	5.8	<0.003	-	27	0.012	-	<0.003
Zinc	51	0.41	-	160	0.046	-	0.042

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Temperature of #2 furnace hearth (°F)	1350-1450	1490
Temperature of #4 furnace hearth (°F)	1450-1550	1550-1560
Ore concentrate feed rate (lb/hr)	1000-1300	1310

- = Not analyzed
Source: USEPA 1989g.

Table 4-1 (continued)

Sample Set No. 5

Constituent	Untreated waste Total (mg/kg)	Untreated waste TCLP (mg/l)	Untreated waste EP leachate (mg/l)	Treated nonwastewater Total (mg/kg)	Treated nonwastewater TCLP (mg/l)	Treated nonwastewater EP leachate (mg/l)	Air pollution control wastewater Total (mg/l)
Antimony	340	0.90	-	2,310	15	-	4.64
Arsenic	300	0.41	0.36	1,250	18	4.7	0.037
Barium	14	0.76	0.14	71	0.16	0.12	0.012
Beryllium	0.15	<0.001	-	0.37	<0.001	-	<0.002
Cadmium	3.0	<0.005	<0.005	7.6	0.13	0.042	<0.004
Chromium (total)	3.1	0.005	<0.003	5.9	<0.003	-	<0.007
Copper	8.7	0.013	-	30.8	<0.003	-	<0.003
Lead	3.1	0.007	<0.028	7.4	<0.005	<0.028	0.018
Mercury	600,000	1.7	0.093	11	0.006	<0.0002	5.48
Nickel	1.3	<0.01	-	3.1	<0.01	-	<0.013
Selenium	2.3	<0.005	<0.005	<0.5	<0.025	<0.05	<0.005
Silver	3.2	<0.004	<0.004	9.5	<0.004	<0.004	<0.003
Thallium	5.1	0.026	-	<1.0	<0.01	-	0.043
Vanadium	5.6	<0.003	-	29	0.004	-	<0.003
Zinc	50	0.38	-	140	0.24	-	0.042

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Temperature of #2 furnace hearth (°F)	1350-1450	1490
Temperature of #4 furnace hearth (°F)	1450-1550	1560-1580
Ore concentrate feed rate (lb/hr)	1000-1300	1370

- = Not analyzed
Source: USEPA 1989g.

Please type in table 4-2

Table 4-2 APCD[a] Cyclone Dust Composition Data from Thermal Recovery of Mercuric Sulfide Ores Collected by EPA at Plant A

Constituent	Untreated Waste Concentration a Total (mg/kg)	a TCLP (mg/kg)	a EP Leachate (mg/kg)	b Total (mg/kg)	b TCLP (mg/kg)	b EP Leachate (mg/kg)
BDAT List Metals						
Antimony	17,200	29.3	-	6,450	24.6	-
Arsenic	2,100	32.3	0.27	520	0.28	33.3
Barium	35	0.28	0.25	27	0.20	0.20
Beryllium	1.1	ND	-	1.0	ND	-
Cadmium	12	0.23	0.25	5.0	ND	0.28
Chromium	4.8	ND	ND	2.8	ND	ND
Cooper	18	ND	-	7.6	ND	-
Lead	23	ND	ND	15	ND	ND
Mercury	2,400	ND	ND	7,900	0.46	0.48
Nickel	4.5	ND	-	3.0	ND	-
Silver	6.6	ND	ND	3.2	ND	ND
Thallium	18.4	ND	-	16.8	ND	-
Vanadium	12.6	ND	-	8.9	ND	-
Zinc	161	0.035	-	87.1	0.009	-
BDAT List Inorganics						
Sulfide	ND	-	-	18,900	-	-
Other Parameters						
Total organic carbon	2,200	-	-	2,200	-	-
Chloride	72,100	-	-	72,400	-	-
Sulfate	22,600	-	-	27,200	-	-

Source: USEPA (1989g)

- = Not analyzed.

[a]APCD = Air pollution control device.

Table 4-3 Treatment Performance Data for Retorting of K106 Hydrazine Sludge Submitted by Plant B

Sample Set No. 1

Constituent	Untreated waste		Treated nonwastewater	
	Total (mg/kg)	EP leachate (mg/l)	Total (mg/kg)	EP leachate (mg/l)
Arsenic	-	-	2.5	0.033
Barium	-	-	48	0.070
Cadmium	-	-	3.0	0.016
Chromium	-	-	38	<0.005
Lead	-	-	56	<0.06
Mercury	4,300	4.8	100	0.0017
Nickel	-	-	39	0.090
Selenium	-	-	<0.6	<0.005
Silver	-	-	6.5	<0.007

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Retort temperature (°F)	1000	1000

- = Not analyzed

Source: Occidental Chemical Corporation 1987.

Table 4-3 (continued)

Sample Set No. 2

Constituent	Untreated waste		Treated nonwastewater	
	Total (mg/kg)	EP leachate (mg/l)	Total (mg/kg)	EP leachate (mg/l)
Arsenic	-	-	2.7	0.030
Barium	-	-	44	0.11
Cadmium	-	-	2.8	0.013
Chromium	-	-	35	<0.005
Lead	-	-	99	<0.06
Mercury	5,500	5.3	90	0.0024
Nickel	-	-	35	0.11
Selenium	-	-	<0.6	<0.005
Silver	-	-	8.3	<0.007

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Retort temperature (°F)	1000	1000

- = Not analyzed

Source: Occidental Chemical Corporation 1987.

Table 4-3 (continued)

Sample Set No. 3

Constituent	Untreated waste Total (mg/kg)	Untreated waste EP leachate (mg/l)	Treated nonwastewater Total (mg/kg)	Treated nonwastewater EP leachate (mg/l)
Arsenic	-	-	1.1	0.021
Barium	-	-	45	0.13
Cadmium	-	-	3.9	0.012
Chromium	-	-	68	<0.005
Lead	-	-	85	<0.06
Mercury	2,500	5.6	47	0.0005
Nickel	-	-	42	0.13
Selenium	-	-	<0.6	<0.005
Silver	-	-	9.9	<0.007

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Retort temperature (°F)	1000	1000

- = Not analyzed

Source: Occidental Chemical Corporation 1987.

Table 4-3 (continued)

Sample Set No. 4

Constituent	Untreated waste		Treated nonwastewater	
	Total (mg/kg)	EP leachate (mg/l)	Total (mg/kg)	EP leachate (mg/l)
Arsenic	-	-	1.0	0.021
Barium	-	-	40	0.14
Cadmium	-	-	4.6	0.015
Chromium	-	-	53	<0.005
Lead	-	-	71	<0.06
Mercury	2,000	5.8	41	<0.002
Nickel	-	-	33	0.12
Selenium	-	-	<0.6	<0.005
Silver	-	-	9.5	<0.007

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Retort temperature (°F)	1000	1000

- = Not analyzed

Source: Occidental Chemical Corporation 1987.

Table 4-4 Treatment Performance Data for Retorting of K106 Hydrazine Sludge Submitted by Plant B-2

Constituent (mercury only)[a]	Untreated waste	Treated nonwastewater	
	Total (mg/kg)	Total (mg/kg)	EP toxicity (mg/l)
Sample Set No. 1	9,825	167.5	0.0033
Sample Set No. 2	7,375	637.5	0.0330
Sample Set No. 3	8,200	470.0	0.0145
Sample Set No. 4	8,750	375.0	0.0011
Sample Set No. 5	32,000	124.0	0.0011
Sample Set No. 6	27,000	205.5	0.0075
Sample Set No. 7	7,875	40.0	0.0017
Sample Set No. 8	17,325	104.0	0.0047
Sample Set No. 9	7,375	60.5	0.0058
Sample Set No. 10	7,125	45.0	0.0031
Sample Set No. 11	5,275	60.0	0.0006
Sample Set No. 12	5,275	110.0	0.0006
Sample Set No. 13	5,400	27.3	0.0008
Sample Set No. 14	4,600	41.8	0.0001
Sample Set No. 15	3,780	87.5	0.0011
Sample Set No. 16	4,390	41.3	0.0080
Sample Set No. 17	3,420	10.5	0.0005
Sample Set No. 18	4,280	544.3	0.0115
Sample Set No. 19	9,640	362.8	0.0295
Sample Set No. 20	5,800	1214.0	0.0525
Sample Set No. 21	6,300	124.5	0.0005
Sample Set No. 22	6,933	268.0	0.0029
Sample Set No. 23	7,200	560.0	0.0220
Sample Set No. 24	8,000	240.0	0.0036
Sample Set No. 25	6,200	77.5	0.0005
Sample Set No. 26	5,100	222.5	0.0018
Sample Set No. 27	5,205	104.0	0.0004
Sample Set No. 28	9,100	765.0	0.0139
Sample Set No. 29	5,650	62.5	0.0008
Sample Set No. 30	2,600	52.5	0.0004
Sample Set No. 31	3,010	29.5	0.0002
Sample Set No. 32	5,480	350.0	0.0071
Sample Set No. 33	6,050	51.0	0.0003
Sample Set No. 34	4,500	1,564.0	0.0502
Sample Set No. 35	6,100	39.2	0.0004

Note: Reported operating temperature of 800-950°F and typical burn time of 14 hours for a batch feed of 11.3 cubic feet.

Source: Oxychem 1989, 1990.

Table 4-5 Treatment Performance Data for Retorting of Mixed K071/K106 Waste from Literature Source A

Constituent	Untreated waste Total concentration (ppm)	Treated waste Total concentration (ppm)
Sample Set No. 1		
Mercury	345	0.5 - 0.8
Sample Set No. 2		
Mercury	255	1.6 - 3.1
Sample Set No. 3		
Mercury	290	1.7 - 2.6
Sample Set No. 4		
Mercury	438	2 - 7.2
Sample Set No. 5		
Mercury	370	1.6

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value SS#1	SS#2	SS#3	SS#4	SS#5
Waste feed rate (lb/hr)	300-700	540	560	580	450	680
Retort temperature (°F)	1200-1400	1400	1250	1350	1350	1386

Source: Perry 1974.

Table 4-6 Treatment Performance Data for Retorting of K106 Sodium Borohydride Sludge Submitted by Plant C

Constituent	Untreated waste Total (mg/kg)	Treated nonwastewater Total (mg/kg)	Treated nonwastewater EP toxicity (mg/l)
Sample Set No. 1			
Mercury	50,000[a]	0.5 - 10[b]	<0.0005
Sample Set No. 2			
Mercury	50,000[a]	0.5 - 10[b]	<0.0005
Sample Set No. 3			
Mercury	50,000[a]	0.5 - 10[b]	<0.0005
Sample Set No. 4			
Mercury	50,000[a]	0.5 - 10[b]	0.0082
Sample Set No. 5			
Mercury	50,000[a]	0.5 - 10[b]	0.0056
Sample Set No. 6			
Mercury	50,000[a]	0.5 - 10[b]	0.0036
Sample Set No. 7			
Mercury	50,000[a]	0.5 - 10[b]	<0.0005

[a]Only an approximate value was given for the untreated waste mercury concentration.

[b]Only one range was given for the treated waste total mercury concentration.

Source: IMC 1982.

Table 4-7 Treatment Performance Data for Stabilization of K106 Collected by EPA at Plant D

Sample Set No. 1

Constituent	Untreated waste Total (ppm)	Untreated waste TCLP (mg/l)	Treated nonwastewater TCLP (mg/l)
BDAT list metals			
Arsenic	1.1	<0.01	<0.004
Barium	74	0.74	0.326
Cadmium	2.3	0.02	<0.003
Chromium	6.3	<0.01	<0.02
Copper	133	<0.02	<0.003
Lead	50	0.13	<0.006
Mercury	25,900	0.01	0.0096
Nickel	14	0.15	<0.025
Silver	131	<0.02	0.007
Vanadium	0.46	<0.01	<0.007
Zinc	443	1.7	<0.013

Sample Set No. 2

Constituent	Untreated waste Total (ppm)	Untreated waste TCLP (mg/l)	Treated nonwastewater TCLP (mg/l)
BDAT list metals			
Arsenic	1.1	<0.01	<0.004
Barium	74	0.74	0.362
Cadmium	2.3	0.02	0.004
Chromium	6.3	<0.01	<0.02
Copper	133	<0.02	<0.003
Lead	50	0.13	<0.0076
Mercury	25,900	0.01	0.023
Nickel	14	0.15	<0.025
Silver	131	<0.02	<0.006
Vanadium	0.46	<0.01	<0.007
Zinc	443	1.7	<0.013

Source: USEPA 1988c.

Table 4-7 (continued)

Sample Set No. 3

Constituent	Untreated waste Total (ppm)	Untreated waste TCLP (mg/l)	Treated nonwastewater TCLP (mg/l)
BDAT list metals			
Arsenic	1.1	<0.01	<0.004
Barium	74	0.74	0.355
Cadmium	2.3	0.02	<0.003
Chromium	6.3	<0.01	<0.02
Copper	133	<0.02	0.005
Lead	50	0.13	<0.006
Mercury	25,900	0.01	0.0093
Nickel	14	0.15	0.027
Silver	131	<0.02	<0.006
Vanadium	0.46	<0.01	<0.007
Zinc	443	1.7	<0.013

Source: USEPA 1988c.

Table 4-8 Treatment Performance Data for Stabilization of D009
(Contaminated Soil and Debris from Natural Gas Pipeline Industry)

Constituent	Untreated waste		Treated Waste
	Total (mg/kg)	TCLP (mg/l)	TCLP (mg/l)
Sample Set No. 1a			
Mercury	26	0.17	0.03
Sample Set No. 1b			
Mercury	26	0.17	0.031
Sample Set No. 2a			
Mercury	24.2	0.16	0.04
Sample Set No. 2b			
Mercury	24.2	0.16	0.167
Sample Set No. 2c			
Mercury	24.2	0.16	0.045
Sample Set No. 3a			
Mercury	89	-	0.04
Sample Set No. 3b			
Mercury	89	-	0.0546
Sample Set No. 4a			
Mercury	33.9	-	0.04
Sample Set No. 4b			
Mercury	33.9	-	0.0744

[a]Range of 2 or 3 reported measurements.

Source: HWTC 1989a,b.

2872g/p.

Table 4-9 Performance Data for Sulfide Precipitation Treatment of K071 Wastewaters Collected by EPA at Plant E

ANALYTICAL DATA:	Sample Set #1		Sample Set #2		Sample Set #3		Filter cake (K106)[a]	
BDAT list constituent	Untreated wastewater (mg/l)	Treated wastewater (mg/l)	Untreated wastewater (mg/l)	Treated wastewater (mg/l)	Untreated wastewater (mg/l)	Treated wastewater (mg/l)	Total (mg/kg)	TCLP (mg/l)
Arsenic	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1	1.1	<0.01
Barium	0.248	0.103	0.226	0.158	0.293	0.144	74	0.74
Cadmium	<0.03	<0.06	<0.06	<0.06	<0.06	<0.06	2.3	0.02
Chromium	<0.06	0.553	0.189	<0.12	<0.12	<0.12	6.3	<0.01
Copper	0.097	<0.16	<0.16	<0.16	<0.16	<0.16	133	<0.02
Lead	<0.66	<1.32	<1.32	<1.32	<1.32	<1.32	50	0.13
Mercury	23.7	0.028	9.25	0.027	77.2	0.028	25,900	0.01
Nickel	0.157	0.275	<0.26	<0.26	<0.26	<0.26	14	0.15
Silver	0.148	<0.1	0.1	<0.1	0.12	<0.1	131	<0.02
Vanadium	<0.04	<0.08	<0.08	<0.08	<0.08	<0.08	0.46	<0.01
Zinc	0.615	0.047	0.88	<0.04	0.535	0.064	443	1.7

DESIGN AND OPERATING PARAMETERS: Parameter	Design value	Operating values		
		Sample Set #1	Sample Set #2	Sample Set #3
Excess sulfide	>40 mg/l	85 mg/l	101 mg/l	96 mg/l

[a]Only one sample of the filter cake (K106) was collected.

Source: USEPA 1988b.

5. DETERMINATION OF BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)

This section presents the rationale for the determination of best demonstrated available technology (BDAT) for mercury-containing nonwastewaters and wastewaters. To determine BDAT, the Agency examines all available performance data for the technologies that are identified as demonstrated for each treatability group to determine whether one of these technologies performs significantly better than the others. All performance data used for determination of best technology must first be adjusted for accuracy, as discussed in EPA's publication Methodology for Developing BDAT Treatment Standards (USEPA 1989a).* BDAT must be specifically defined for all streams associated with the management of the listed waste or wastes; this includes the original waste as well as any residual waste streams created by the treatment process.

The technology that performs best on a particular waste or waste subcategory is then evaluated to determine whether it is "available." To be available, the technology must (1) be commercially available to any generator and (2) provide "substantial" treatment of the waste, as determined through evaluation of accuracy-adjusted data. In determining whether a technology is available, EPA may consider data on the performance of a waste similar to the waste in question, provided that the similar waste is at least as difficult to treat.

---

*Accuracy adjustment accounts for the ability of an analytical technique to recover a particular constituent from the waste in a particular test. The recovery of a constituent is determined by spiking a sample with a known amount of the target constituent and then comparing the result of analysis of the spiked sample with the result from the unspiked sample.

5.1 BDAT for Nonwastewaters

EPA reviewed the available treatment performance data for mercury-containing wastes presented in Section 4 to determine whether they represent the operation of well-designed and well-operated systems and whether sufficient quality assurance/quality control (QA/QC) data were collected to assess the accuracy of the treated waste analyses. Identification of BDAT for nonwastewaters is discussed below for each treatability group.

5.1.1 Inorganic Mercury Nonwastewaters - High-Mercury Subcategory

EPA has identified several thermal mercury recovery technologies, including retorting, roasting, batch vacuum or steam distillation, and a proprietary process as demonstrated technologies for inorganic mercury nonwastewaters in the High-Mercury Subcategory. The Agency has also identified thermal processing of mercuric sulfide (cinnabar) ores as a technology that is used to recover mercury from wastes more difficult to treat than most inorganic mercury wastes because of the higher mercury content in these ores than in the mercuric sulfide-containing wastes for which EPA has waste composition data (see Section 3.2.1).

For treatment of wastes in which mercury is present as metallic mercury or as inorganic mercury compounds, the Agency has data from five tests as follows:

- Five sets of performance data (presented in Table 4-1) from recovery of mercury from cinnabar ores by a thermal treatment process that is very similar to retorting waste treatment processes;
- Three sets of performance data from retorting of K106 generated by hydrazine treatment of mercury-containing wastewaters (presented in Table 4-3);

- Thirty-five sets of performance data from retorting of K106 generated by hydrazine treatment of mercury-containing wastewaters (presented in Table 4-4);

- Five sets of performance data from retorting of a mixed K071/K106 waste (presented in Table 4-5) that contained 95 percent K071 and 5 percent K106 sulfide sludge; and

- Seven sets of performance data from retorting of K106 generated by borohydride reduction treatment (presented in Table 4-6).

The treatment data presented in Table 4-1 include total composition, TCLP leachate, and EP leachate data for both the untreated waste and treated nonwastewater residual as well as total composition data for the air pollution control wastewaters (primarily SO_2 scrubber waters). Quality assurance/quality control (QA/QC) information was also provided. The data presented in Table 4-3 include total and EP Toxicity procedure leachate concentrations for mercury and the other EP metals for the treated nonwastewater, as well as design and operating information. QA/QC information (analytical recoveries) was also provided with these data. The treatment data presented in Table 4-4 include total and EP Toxicity procedure leachate concentrations for mercury only. QA/QC information was not provided. The data in Table 4-5 include a range of total mercury concentrations in the treated nonwastewater for each test, as well as design and operating data. EPA considered the highest value of the range in each test as the value that represented treatment performance for that test. No analytical QA/QC data were provided. However, from the detail of the analytical method provided in the report, EPA believes that the data were adjusted for analytical recovery before presentation in the report. The data in Table 4-6 present the EP leachate mercury concentration for each sample set for the treated nonwastewater but only a range of total mercury concentrations for the seven sample sets. No QA/QC data were provided. However, these data sets indicate that the performance achieved by retorting K106 borohydride sludge is similar to the performance achieved by retorting mixed K071/K106 sludges.

The treatment performance data presented in Table 4-1 and Tables 4-3 through 4-5 were adjusted for analytical recovery to take into account analytical interferences associated with the chemical makeup of the treated waste samples. In the QA/QC test for analytical recovery, EPA first analyzes a waste for a constituent and then adds a known amount (i.e., a spike) of the same constituent to the waste material and reanalyzes the sample for that constituent. The difference between the total amount detected after spiking and the concentration detected in the unspiked sample divided by the amount of spike added is the recovery value. (If recovery tests are run in duplicate, EPA uses the lower recovery value.) The reciprocal of the recovery multiplied by the analytical value obtained during performance testing is the accuracy-corrected value used in comparing treatment effectiveness and subsequently in calculating treatment standards. Percent recovery values for constituents detected in the mercury ores tested are presented in Appendix A. The accuracy adjustment of performance data for total mercury for thermal processing of mercury ores is detailed in Table 5-1 (at the end of this section).

The design and operating data provided in Table 4-1 show that the thermal ore processing system was well operated during the test. Even though the total composition mercury data from this test show higher mercury concentrations in the residual from thermal ore processing than for the K071/K106 retorting test, the EP Toxicity procedure and TCLP leachates from the ore processing residuals show that mercury leaches from these residuals at very low levels. The range of TCLP leachate concentrations for mercury in these residuals, reported in Table 4-1, is 0.0002 to 0.006 mg/l (ppm). The EP leachate concentrations reported for mercury in the same table are all below 0.0002 mg/l (ppm).

The design and operating data presented in Tables 4-3 and 4-4 for the K106 hydrazine sludge indicate that this retorting test was performed at a much lower temperature (800-1000°F) than was the test of the mixed K071/K106 wastes (1250-1400°F). This could account for the poorer treatment performance in this test.

Based on the data presented for thermal treatment of mercury wastes in Table 5-1, retorting for recovery of mercury has been determined to be the best technology for treatment of inorganic mercury nonwastewaters. All of the treatment data for thermal mercury recovery processes presented in Section 4 show that substantial treatment is achieved based on the reduction in total, TCLP, and EP leachate mercury concentrations in the treated nonwastewater compared to that in the untreated waste. The thermal ore processing technology is used at the one U.S. mine that is known to process mercury ores. Similar technologies (retorting and roasting) are used or have been used at several chloralkali facilities in the U.S. and in Europe to process mercury wastewater treatment sludges. In addition, comparing the melting/boiling/sublimation/decomposition temperatures presented in Table 5-2 (i.e., for inorganic mercury compounds known to be present in inorganic mercury nonwastewaters) to the operating temperatures of the retorters/roasters in which K106 and K106/K071 wastes have been successfully retorted (800 to 1500°F) (Tables 4-1 through 4-5) clearly indicates that the mercury compounds present in the listed mercury wastes, as well as most mercury compounds listed in Appendix B, should be amenable to thermal recovery by retorting/roasting. Therefore, thermal recovery of mercury is available and thus has been determined to be BDAT for inorganic mercury nonwastewaters. This is in accordance with the strong policy in RCRA--both in the land ban and in general provisions--to utilize recovery technologies as the preferred waste management option.

During the comment period for the proposed rule, EPA received numerous comments disputing EPA's determination that retorting/roasting had been demonstrated for high-mercury content nonwastewaters. The commenters' arguments were based, to a large extent, on the results of a recent study entitled Test Results for Thermal Desorption Treatment of K106 Chlorine Production Waste which, was prepared for The Chlorine Institute (PEI Associates 1989). This study reported significant operational problems and poor elemental mercury recovery when pilot-scale

retorting experiments of K106 wastes were conducted. Several commenters have attributed the poor results to the high concentration of chloride salts present in K106 that likely interfere with the overall performance. In addition, several commenters expressed concern about potential increased emissions of mercury and sulfur dioxide as a result of thermal processing.

EPA has carefully reviewed this PEI study and the various comments submitted to the Agency concerning the significance of the findings of the report. A detailed review of this study is provided in a memo from A. Paintal to the Administrative Record - Docket LD12REF/7.16.2.11. EPA has determined that the operational and recovery problems experienced can likely be attributed to inadequate furnace design, operational controls, and recovery system design. With regard to furnace design and associated operational controls, EPA believes that multiple hearth furnaces, rather than the rotary kiln used by PEI Associate, are more appropriate for retorting K106 wastes based on the results of Perry (1974) and USEPA (1989g), which indicate that multiple hearth furnaces provide better control over residence time and eliminate short-circuiting.
With respect to recovery system design, PEI Associates used a design in which the condenser was placed after the scrubber system. EPA believes that the appropriate placement of the condenser in the recovery system is before the scrubber system.

With respect to the potential interference of chloride salts, no convincing arguments have been made to substantiate the claim that chloride salts will interfere with the overall performance of the retorter/roaster. In fact, retorting of a mixed waste composed of 5 percent K106 and 95 percent K071 has been demonstrated in Perry (1974). EPA believes that since it is demonstrated that mercury can be removed from this feed material, which has a higher concentration of chloride salts (because of the K071 waste) than pure K106, chloride salts should not be a source of major performance impairment. (Untreated K071 wastes contain from 5 to 67 percent sodium chloride (USEPA 1988g). Untreated K106 wastes contain 0.6 to 4.7 percent chlorides (Chlorine

Institute 1988)). In addition, Perry (1974) reported that acid pretreating of the sludge prior to retorting increased the mercury removal from the waste. Although the reason(s) for this increase in effectiveness was not identified, the study results indicate that pretreating the waste can improve its amenability to treatment.

With respect to concerns about increased air emissions, EPA fully expects that both mercury and sulfur dioxide emissions can be effectively controlled by well-designed and well-operated air pollution control equipment that allows for recovery of mercury. Perry (1974) reported greater than 90 percent removal of mercury from the condenser exhaust as it passed through a chilled water heat exchanger and a Brink demister. Perry (1974) also reported dust plugging problems in the condensers that might have resulted in lower overall mercury recovery than could be achieved. Similar dust problems were solved by placing a cyclone scrubber before the condenser (USEPA 1989g).

EPA believes that existing Clean Air Act (CAA) controls can address any potential problems. The National Emission Standard for Hazardous Air Pollutants (NESHAP) for mercury emissions (40 CFR Part 61, Subpart E) limits mercury emissions from mercury cell chloralkali facilities and mercury ore processing facilities. However, to ensure that air emissions of mercury are controlled adequately, the Agency is specifying as part of BDAT that the retorting/roasting unit (or the facility) be subject to one or more of the following: (1) a NESHAP for mercury; (2) a best available control technology (BACT) or LAER standard for mercury imposed pursuant to a PSD permit; or (3) a State permit that establishes emission limitations (within the meaning of Section 302 of the Clean Air Act) for mercury. The Agency believes that with such air emissions controls, retorting/roasting is a treatment technology that minimizes threats to human health and the environment and so satisfies the requirements of Section 3004(m).

A discussion of air pollution control technologies capable of meeting the mercury NESHAP requirements is provided in USEPA 1984.

For P065, EPA has determined that incineration represents BDAT. EPA believes this is necessary to remove the reactive characteristic of mercury fulminate and to enable further treatment or recovery of mercury (USEPA 1990).

5.1.2 Inorganic Mercury Nonwastewaters - Low-Mercury Subcategory

EPA has identified acid leaching as the only demonstrated treatment technology for inorganic mercury nonwastewaters with total mercury concentrations too low to be amenable to recovery by thermal recovery technologies (i.e., the Low-Mercury Subcategory). Evaluation of these data for proper system design and operation and calculation of accuracy-adjusted treatment data are included in the BDAT background document for K071 (USEPA 1988b).

5.1.3 Organic Mercury Nonwastewaters

EPA has identified incineration, retorting, and roasting as demonstrated technologies for treatment of mercury-containing nonwastewaters that contain organomercury constituents (such as phenylmercuric acetate) or that contain mercury in an organic waste matrix. Data available to the Agency are specifically on incineration of organic metallic nonwastewaters and retorting of D009 spent catalysts.

Incineration is applicable and demonstrated for treatment of wastes containing organic and organometallic constituents. Treatment using incineration technologies will destroy the organic constituents of the waste. As a consequence of destruction of the organics, incineration will break the organo-metal bond in the organometallic waste constituents.

The metallic part of the organometallic constituents in the waste, as well as any metals present in the waste, will remain in the residual (ash) generated, will be removed from the gases exiting the incinerator by the air pollution control equipment, or will remain in the gases exiting the incineration system. Therefore, incineration has been determined to be BDAT for P092 and D009 organic mercury nonwastewaters, followed by treatment of the ash and scrubber water residuals by the BDAT specified for inorganic high- or low-mercury nonwastewaters (depending on mercury concentration in the ash) and mercury-containing wastewaters as discussed in Sections 5.1.1 and 5.2, respectively.

At least one facility submitted data showing that wastes with concentrations of semivolatile organics up to 30 percent are currently being retorted outside the United States. The facility described its waste as a mercury spent catalyst contaminated with an intermediate chemical used in the manufacture of polymers. The facility sends this D009 waste overseas for the purpose of direct retorting of mercury. Based on this information, EPA believes that retorting/roasting can be promulgated as an alternative treatment standard for some organometallic nonwastewater forms of P092 and D009 wastes.

5.1.4 Nonwastewaters Containing Radioactive Materials

In Section 2.3.4, EPA discussed two subcategories of nonwastewaters containing reactive materials that have been reported to be generated by DOE. These were described as metallic mercury-containing radioactive materials and waste hydraulic oil contaminated with metallic mercury and radioactive materials.

The Agency has no data or information to indicate that thermal mercury recovery processes that are demonstrated for treatment of inorganic high-mercury nonwastewaters would be able to separate the mercury from the

radioactive material (tritium) that is the contaminant in the metallic mercury waste generated by DOE. Thus, the Agency believes that technologies demonstrated for these wastes are the absorption technologies discussed in Section 3.1.1(7). Common absorbents used are zinc dust, calcium disulfide, and flowers of sulfur. EPA prefers amalgamation with zinc over conventional spill cleanup procedures involving addition of calcium polysulfide or flowers of sulfur because the use of zinc results in lower air emissions of mercury.

The Agency currently has no information on whether this procedure will reduce the overall leachability of mercury. However, the Agency has determined that this procedure does provide significant treatment because of the decrease in air emissions, the change in mobility from liquid mercury to a paste-like solid, and the potential reduction in leachability due to the amalgamation with zinc. Based on this information, the general lack of treatment data, the lack of alternative technologies, and the unique handling problems associated with radioactivity, the Agency has determined that amalgamation with zinc represents the best technology for treatment of elemental mercury wastes contaminated with radioactive materials.

EPA feels that incineration, which is demonstrated for treatment of nonradioactive organic mercury nonwastewaters, is also demonstrated for treatment of waste hydraulic oil contaminated with mercury and radioactive materials (tritium). However, EPA does not expect recovery technologies to be applicable to the treatment of nonwastewater residuals generated from incineration treatment of this waste because of the radioactive nature of the waste. Therefore, the best technology for treatment of the nonwastewater residuals generated from incineration of this waste is determined to be acid leaching.

5.2 BDAT for Wastewaters

EPA has identified chemical precipitation followed by filtration, carbon adsorption, and ion exchange as demonstrated technologies for treatment of mercury-containing wastewaters where the mercury constituent is inorganic. EPA has identified chemical oxidation followed by chemical precipitation and filtration, incineration, ion exchange, and carbon adsorption as demonstrated technologies for the treatment of wastewaters containing organomercury constituents or inorganic mercury in an organic waste matrix.

As discussed in Section 4, EPA does not have treatment data for wastewaters generated from retorting. However, EPA does have chemical precipitation treatment data for K071 mercury-containing wastewaters, which are presented in Table 4-9. The Agency has determined that these wastewaters are at least as difficult to treat as wastewaters generated from retorting because the concentrations of mercury and other metals are similar and neither waste contains significant concentrations of any interfering substances. These wastewaters are also expected to be at least as difficult to treat as other mercury-containing wastewaters that would be classified as D009 wastes because of the relatively high concentration of mercury in the K071 wastewaters and because the Agency has no data indicating that D009 wastewaters are routinely generated containing significant concentrations of constituents (such as oil and grease) that would affect the performance of chemical precipitation treatment. This technology substantially reduces the concentration of mercury in wastewaters, as noted in Table 4-9, where untreated mercury concentrations of as much as 77 mg/l are treated to 0.028 mg/l.

EPA has no data on the demonstrated adsorption technologies (ion exchange and carbon adsorption). However, when these technologies are used, a regenerant solution is produced that either is recycled or must

be treated by chemical precipitation. Therefore, the chemical precipitation treatment standard would ultimately apply to wastewaters generated by these technologies.

Data collected by the Agency on treatment of K071 wastewater by sulfide precipitation and filtration are shown in Table 4-9. Operating data collected during treatment of this waste show that these data represent the performance of a well-designed, well-operated treatment system. EPA adjusted the data values based on the analytical recovery values in order to take into account analytical interferences associated with the chemical makeup of the treated sample. Accuracy adjustment of mercury concentrations for these treatment data is detailed in Table 5-2. The analytical recovery values used in these calculations are presented Appendix A.

EPA's determination of substantial treatment is based on the observed reduction in total mercury concentration from 77.2 ppm to 0.028 ppm in the K071 mercury-containing wastewaters considered by EPA to be similar to other inorganic mercury-containing wastewaters.

The Agency believes that this reduction in the concentration of hazardous constituents is substantial and that sulfide precipitation followed by filtration is available to treat these wastes because it is a common commercially available wastewater treatment technology. Therefore, sulfide precipitation followed by filtration represents BDAT for these wastewaters.

EPA does not have data on the effectiveness of chemical oxidation treatment of wastewaters contaminated with organics or organomercury compounds followed by chemical precipitation and filtration to enable the Agency to compare this treatment to the performance of sulfide precipitation treatment of inorganic mercury wastewaters. Lacking these

data, EPA has determined that chemical precipitation is also the best technology for the treatment of organic mercury wastewaters.

Incineration may be required as a pretreatment method for organometallic wastes to destroy the organics and concentrate the metals in the residual ash or the incineration scrubber waters. Resulting scrubber waters would be expected to be free of organics; therefore, mercury in these wastewaters is then expected to be able to be treated by chemical precipitation with effectiveness similar to that of treatment of inorganic mercury wastewaters. Chemical oxidation may also be effective as a pretreatment method for organics prior to chemical precipitation.

EPA has no data on the demonstrated adsorption technologies (ion exchange and carbon adsorption), but these technologies ultimately generate a residual (the spent carbon or ion exchange resin) that must be thermally processed (incinerated or retorted) to recover mercury. (In the cases where the mercury is adsorbed as an organomercury compound, incineration may be the only thermal treatment option.) Therefore, either retorting/roasting or incineration is ultimately the best technology for treatment of nonwastewater residuals generated by these treatment technologies, and the incineration treatment standard also applies to nonwastewater residuals generated from the use of these technologies to treat organic mercury wastewaters.

No data are available on the treatment of P065 wastewaters or D009 reactive mercury wastewaters by the demonstrated technologies identified in Section 3.2.2 (aqueous chemical deactivation and incineration). However, based on the demonstrated effectiveness of incineration of other explosive and reactive D001 wastes (USEPA 1989e), the Agency has determined that BDAT for these mercury nonwastewaters (incineration in specially-designed units) followed by treatment of scrubber waters produced from incineration by the BDAT for inorganic mercury wastewaters

(chemical precipitation followed by filtration) is BDAT for these mercury wastewaters (P065 and explosive D009 wastewaters). The determination is based on the reasons that were discussed in Section 5.1.3 for explosive mercury nonwastewaters and in Section 5.2 for inorganic mercury wastewaters.

Table 5-1 Summary of Accuracy Adjustment of Treatment Data for Total Mercury Generated from Thermal Recovery Technologies

	Untreated waste concentration (mg/kg)	Measured treated waste concentration (mg/kg)	Percent recovery for treated waste matrix	Accuracy correction factor	Accuracy-adjusted concentration (mg/kg)
Thermal Treatment of Mercuric Sulfide Ores					
Sample Set No. 1	625,000	45	113	1.0	45
Sample Set No. 2	738,000	42.4	113	1.0	42.4
Sample Set No. 3	640,000	36	113	1.0	36
Sample Set No. 4	473,000	23	113	1.0	23
Sample Set No. 5	600,000	11	113	1.0	11
Retorting of K106 Hydrazine Sludge (Plant B)					
Sample Set No. 1	4,300	100	89	1.12	112
Sample Set No. 2	5,500	90	89	1.12	101
Sample Set No. 3	2,500	47	89	1.12	53
Sample Set No. 4	2,000	41	89	1.12	46
Retorting of K106 Hydrazine Sludge (Plant B-2)					
Sample Set No. 1	9,825	NA	NA	NA	167.5
Sample Set No. 2	7,375	NA	NA	NA	637.5
Sample Set No. 3	8,200	NA	NA	NA	470.0
Sample Set No. 4	8,750	NA	NA	NA	375.0
Sample Set No. 5	32,000	NA	NA	NA	124.0
Sample Set No. 6	27,000	NA	NA	NA	205.5
Sample Set No. 7	7,875	NA	NA	NA	40.0
Sample Set No. 8	17,325	NA	NA	NA	104.0
Sample Set No. 9	7,375	NA	NA	NA	60.5
Sample Set No. 10	7,125	NA	NA	NA	45.0
Sample Set No. 11	5,275	NA	NA	NA	60.0
Sample Set No. 12	5,275	NA	NA	NA	110.0
Sample Set No. 13	5,400	NA	NA	NA	27.3
Sample Set No. 14	4,600	NA	NA	NA	41.8
Sample Set No. 15	3,780	NA	NA	NA	87.5
Sample Set No. 16	4,390	NA	NA	NA	41.3
Sample Set No. 17	3,420	NA	NA	NA	10.5
Sample Set No. 18	4,280	NA	NA	NA	544.3
Sample Set No. 19	9,640	NA	NA	NA	362.8
Sample Set No. 20	5,800	NA	NA	NA	1214.0
Sample Set No. 21	6,300	NA	NA	NA	124.5
Sample Set No. 22	6,933	NA	NA	NA	268.0
Sample Set No. 23	7,200	NA	NA	NA	560.0
Sample Set No. 24	8,000	NA	NA	NA	240.0
Sample Set No. 25	6,200	NA	NA	NA	77.5
Sample Set No. 26	5,100	NA	NA	NA	222.5
Sample Set No. 27	5,205	NA	NA	NA	104.0
Sample Set No. 28	9,100	NA	NA	NA	765.0

Table 5-1 (continued)

	Untreated waste concentration (mg/kg)	Measured treated waste concentration (mg/kg)	Percent recovery for treated waste matrix	Accuracy correction factor	Accuracy-adjusted concentration (mg/kg)
Retorting of K106 Hydrozine Sludge (Plant B-2) (cont'd)					
Sample Set No. 29	5,650	NA	NA	NA	62.5
Sample Set No. 30	2,600	NA	NA	NA	52.5
Sample Set No. 31	3,010	NA	NA	NA	29.5
Sample Set No. 32	5,480	NA	NA	NA	350.0
Sample Set No. 33	6,050	NA	NA	NA	51.0
Sample Set No. 34	4,500	NA	NA	NA	1,564.0
Sample Set No. 35	6,100	NA	NA	NA	39.2
Retorting of Mixed K071/K106					
Sample Set No. 1	345	NA	NA	NA	0.8
Sample Set No. 2	255	NA	NA	NA	3.1
Sample Set No. 3	290	NA	NA	NA	2.6
Sample Set No. 4	438	NA	NA	NA	7.2
Sample Set No. 5	370	NA	NA	NA	1.6

NA = Not available. Data from Oxychem 1989 (Plant B-2) and Perry 1974, as presented in Table 4-4 and Table 4-5, respectively, are assumed to have been corrected for accuracy of the analytical method.

Table 5-2 Mercury Compounds Known To Be Present in Listed Mercury Wastes and Their Melting Points, Boiling Points, and Behavior

Mercury compound (mg/l)	Listed waste(s) containing the compound	Melting point (8 C)	Boiling point	Behavior upon heating (8 C)	Solubility in water[a]
Organic compounds					
Phenymercuric acetate	P092	149	-	-	sl.s
Other mercury compounds	D009	-	-	-	-
Inorganic compounds					
Mercury	K106, D009, K071	-38.9	357	-	i
Mercuric acetate	D009	-	-	Decomposes	250,000
Mercurous chloride	D009	303	384	Sublimes	0.2
Mercuric chloride	K071, D009	265	303	Sublimes	71,500
Mercury fulminate	P065	-	-	Explodes	sl.s
Mercury hydroxide	K106	-	-	-	-
Mercuric hydroxide	K106	-	-	-	-
Mercuric nitrate	D009	79	-	Decomposes	v.s.
Mercurous oxide	K106, D009	100	-	Decomposes at 100 C	i
Mercuric oxide	K106, D009, K071	-	-	Decomposes above 400 C	50
Mercuric sulfide	K106, D009	446	-	Sublimes	i

Sources: Singer and Nowak (1978); McGraw-Hill (1982); Weast (1977).

[a]Numbers given are quantitative solubilities in water (10-25 C). Solubility abreviations describe the solubility as follows:

i = insoluble
sl.s. = slightly soluble
v.s. = very soluble

Table 5-3 Summary of Accuracy Adjustment of Treatment Data for Total Mercury in Wastewaters

	Untreated waste concentration (mg/l)	Measured treated waste concentration (mg/l)	Percent recovery for treated waste matrix	Accuracy correction factor	Accuracy-adjusted concentration (mg/l)
Chemical Precipitation					
Sample Set No. 1	23.7	0.028	95	1.05	0.0295
Sample Set No. 2	9.25	0.027	95	1.05	0.0284
Sample Set No. 3	77.2	0.028	95	1.05	0.0295

6. SELECTION OF REGULATED CONSTITUENTS

In Section 5, the best demonstrated available technology (BDAT) was determined for each waste treatability group for the mercury-containing wastes K106, U151, P065, P092, and D009. This section describes the selection of constituents to be regulated for each waste code. The selected constituents must be present in the untreated waste at concentrations that are treatable by the chosen BDAT discussed in Section 5.

6.1 Nonwastewaters

In the EPA treatment test of thermal processing of mercuric sulfide ores, the Agency analyzed the untreated ore samples for BDAT list metals and BDAT list organic compounds, as well as for total organic carbon (TOC). No treatable concentrations of organic compounds were detected in these samples. Thus, these ores are similar to the K106 mercuric sulfide sludge wastes as generated (see Table 2-4).

The mercuric sulfide ores sampled by EPA were not analyzed for certain compounds on the BDAT list (specifically, organochlorine pesticides, phenoxyacetic acid herbicides, organophosphorus insecticides, PCBs, and dioxins and furans) because the Agency is not aware of any in-process source of these constituents and would therefore not expect any of these constituents to be present at treatable concentrations. Two inorganics other than metals on the BDAT list (fluoride and cyanide) were not analyzed. Even though these constituents were not analyzed, EPA would not expect fluoride or cyanide to be present at treatable concentrations in the wastes tested.

The K106 hydrazine sludge treated at Plant B was analyzed only for the eight characteristic metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver). None of the metals other than

mercury were detected at treatable concentrations in this K106 waste. Results of retorting treatment of the mixed K071/K106 sludge reported in Literature Source A (see Table 4-5) presented only total mercury concentrations. However, no treatable concentrations of other BDAT list constituents were expected to be detected in this waste. Results of retorting of K106 at Plant C (presented in Table 4-6) also reported only mercury concentrations. No other BDAT list constituents were expected to be present at treatable concentrations in this waste.

Upon analysis of data on characterization and treatment of K071 and K106 wastes generated in the mercury cell chloralkali process and available information about this process, EPA concludes that mercury is the only BDAT list constituent expected to be routinely present in wastes from this process. Thus, the Agency has determined that mercury is the only regulated constituent for K106.

For P065, P092, and U151, mercury is expected to be the only BDAT list metal constituent of the waste (unless the wastes are mixed with other listed or characteristic hazardous wastes, in which case other treatment standards would also apply). P092 is also expected to contain organic BDAT constituents (benzene, in particular). Mercury has been selected as the only regulated constituent for these U- and P-code mercury-containing wastes. No data are available to EPA on the treatment of organics in P092 wastes. However, the Agency expects the organic constituents of P092 to be destroyed by incineration of P092 wastes, which is required as a method of treatment. EPA also expects that the fulminate constituent of P065 (mercury fulminate) and the reactive constituents of D009 reactive wastes will be destroyed by incineration, which is required as a method of treatment for organic mercury wastes. Incineration also removes the reactivity characteristic associated with these wastes.

Mercury has also been selected as the only constituent for regulation for D009 wastes. EPA does not have sufficient characterization data for D009 wastes to determine whether these wastes commonly contain other BDAT list constituents at treatable concentrations. If these wastes contain organic constituents, EPA believes that these constituents will be destroyed by incineration, which is a required method of treatment for organic D009 nonwastewaters.

6.2 Wastewaters

EPA does not have data on the composition or treatment of K106 wastewaters generated from retorting. However, EPA does have data that indicate that mercury is the only BDAT constituent present in wastewaters generated from recovery of mercury from mercuric sulfide ores in a multiple-hearth furnace (see Table 4-1). EPA would not expect any BDAT constituent other than mercury to be present in treatable quantities in the K106 wastewater for reasons already presented in the discussion of nonwastewaters. Mercury has therefore been selected as the only regulated constituent for K106 wastewaters.

Mercury has been selected as the only regulated constituent in P065, P092, U151, and D009 wastewaters. Mercury is the only constituent for which these wastes are listed and is the only BDAT list constituent expected to be present in these wastes, with the following exceptions:

- If these wastes are mixed with other listed or characteristic hazardous wastes, other appropriate treatment standards would also apply.
- For P092 and organic D009 wastes, organic constituents will be present; incineration is required as a method of treatment for these organics.
- For P065 (which may be reactive) and reactive D009 wastes, incineration is required as a method of treatment for the reactivity characteristic of these wastes.

7. CALCULATION OF TREATMENT STANDARDS

This section presents the calculation of the proposed numerical treatment standards for K106, P065, P092, U151, and D009 wastes using the treatment data presented for the best demonstrated available technologies, as determined in Section 5. In Section 6, mercury was selected as the only regulated constituent for both nonwastewater and wastewater forms of the wastes.

The Agency bases treatment standards for regulated constituents on the performance of well-designed and well-operated BDAT treatment systems. These standards must account for analytical limitations in available performance data and must be adjusted for variabilities related to treatment, sampling, and analytical techniques and procedures.

BDAT standards are determined for each constituent by multiplying the arithmetic mean of accuracy-adjusted constituent concentrations detected in treated waste by a "variability factor" specific to each constituent for each treatment technology defined as BDAT. Accuracy adjustment of performance data was discussed in Section 5 in relation to defining BDAT. Variability factors account for normal variations in the performance of a particular technology over time. They are designed to reflect the 99th percentile level of performance that the technology achieves in commercial operation. (For more information on the principles of calculating variability factors, see EPA's publication Methodology for Developing BDAT Treatment Standards (USEPA 1989a).) Details on the calculation of variability factors for mercury-containing nonwastewaters and wastewaters are presented in this section.

Where EPA has identified BDAT for a particular waste, but because of data limitations or for some other compelling reason cannot define specific numerical treatment standards for that waste, the Agency can

require the use of that treatment process as a technology standard. The rationale for specifying technology standards for certain mercury wastes or waste groups, either in lieu of or in addition to numerical treatment standards, is also discussed in this section.

7.1 Wastewaters

7.1.1 K106, P065, P092, and U151 Wastewaters

EPA collected three sets of untreated and treated K071 wastewater data from one facility using sulfide precipitation followed by filtration. The following steps were taken to derive the numerical BDAT treatment standards for K106, P065, P092, and U151 wastewaters:

- Accuracy-corrected constituent concentrations were calculated for mercury. These calculations are presented in Table 5-2.
- The Agency evaluated the data collected from the sulfide precipitation treatment system to determine whether any of the data represented poor design or poor operation. The available design and operating data show that all three data sets collected from the Agency testing for wastewater represent the performance of a well-designed, well-operated system.
- An arithmetic average concentration level and a variability factor were determined for the BDAT list constituent (i.e., mercury) regulated in this waste.
- The BDAT treatment standard for mercury was determined by multiplying the average accuracy-corrected total concentration by the variability factor, which has been calculated to be 1.05.

Table 7-1 (at the end of this section) summarizes the calculation of the numerical treatment standards for K106, P065, P092, and U151 wastewaters. For all wastewater forms of K106, P065, P092, and U151, EPA is promulgating a treatment standard of 0.030 mg/l. The treatment standard is based on the performance of sulfide precipitation treatment of K071 wastewaters. Some mercury-containing wastewaters may require

additional or different treatment trains in order to treat other metals or organics that may interfere with the treatment of mercury. Pretreatment by an oxidation step (with reagents such as hydrogen peroxide or sodium hypochlorite) or incineration may be necessary to treat the organics in P092 wastewaters. Pretreatment by aqueous chemical deactivation or by incineration in specially-designed thermal treatment units may be necessary to treat reactive constituents in P065 wastewaters. The treatment standard for K106, P065, P092, and U151 wastewaters is presented in Table 7-3 at the end of this section.

EPA is specifying further that, for treatment standards expressed as methods of treatment, certain regulatory conditions must be met. Incinerators must be operated in accordance with the provisions under 40 CFR Part 264, Subpart O, or Part 265, Subpart O. Also, EPA is specifying that, as part of the BDAT, the retorting/roasting unit (or facility) must be subject to one or more of the following: (1) NESHAP for mercury, (2) a PDS permit, or (3) a State permit that establishes emission limitations pursuant to Section 302 of the Clean Air Act for mercury.

The Agency believes that with such air emission controls retorting is a treatment technology that minimizes threats to human health and the environment and so satisfies the requirements of section 3004(m). (The Agency's authority to impose these conditions on performance of a mercury retorting device comes directly from its authority under section 3004(m) to establish methods of treatment. EPA is indicating here that part of the designated method includes operating pursuant to standards that prevent cross-media contamination. Such standards are enforceable under RCRA pursuant to the authority in section 3008(a).)

7.1.2 D009 Wastewaters

For D009 wastewaters, EPA proposed two regulatory options. One regulatory option would have required treatment of these wastes to comply with a treatment standard of 0.030 mg/l. The second regulatory option was to require treatment of these wastes to meet a treatment level of 0.20 mg/l (the toxic characteristic level for mercury). In the proposed rule, EPA solicited comments on the merits of each of these approaches. The Agency received many comments and reviewed each carefully before deciding to regulate D009 wastewaters at the characteristic level of 0.20 mg/l. Even though the data available to EPA indicate that a treatment standard of 0.030 mg/l is achievable for many D009 wastewaters, EPA is adopting the characteristic level of 0.20 mg/l as the treatment standard for D009 wastes for reasons outlined in Section III.D of today's final rule for Third Third wastes. In addition, available data indicate that even the most difficult to treat D009 wastewaters can be treated to the characteristic level of 0.20 mg/l. The treatment standard for D009 wastewaters is presented in Table 7-4.

7.2 Nonwastewaters

For nonwastewater forms of K106, U151, P065, P092, and D009, EPA is establishing two general mercury subcategories: a High-Mercury Subcategory and a Low-Mercury Subcategory. A total mercury concentration of 260 mg/kg has been established to classify these mercury wastes into one of these two subcategories and to determine compliance with the treatment standards.

The retorting performance data from K071/K106 were used to determine a level of mercury that would classify a waste as either a high-mercury waste or a low-mercury waste. EPA has determined that the cutoff level is 260 mg/kg. This is the lowest untreated waste mercury concentration

for which retorting was demonstrated (i.e., 255 mg/kg rounded to 260 mg/kg) with approximately 99 percent recovery of mercury. This cutoff level was determined from retorting a mixed K106/K071 nonwastewater (Table 4-5) (a difficult waste to retort, as discussed earlier) and is a far lower feed concentration than all other retorting data (Tables 4-1, 4-3, and 4-4), in which untreated mercury total composition always exceeds 2,500 mg/l.

Also, the Agency is setting additional restrictions for the disposal of treatment residues resulting from incinerators, retorters, or roasters. These additional restrictions are expressed as a requirement for further treatment (e.g., further retorting) or a requirement for compliance with a maximum concentration of leachable mercury acceptable for disposal (e.g., TCLP mercury leachate below 0.20 mg/l for residues from retorters and roasters). EPA believes these additional requirements will adequately minimize the commenters' concern of having a more leachable mercury in incinerated, retorted, or roasted wastes. The Agency's authority to impose these additional conditions comes directly under Section 3004(m).

7.2.1 K106 and U151 Nonwastewaters

For nonwastewater forms of K106 and U151 in the High-Mercury Subcategory, EPA is promulgating a treatment standard of retorting/roasting. Nonwastewater residues from retorting/roasting are not prohibited from land disposal unless they leach mercury above 0.20 mg/l, as measured by TCLP. Nonwastewater residues unacceptable for land disposal (i.e., those that leach mercury at levels exceeding 0.20 mg/l) are required to comply with the appropriate standards (i.e., High- or Low-Mercury Subcategory) as a prerequisite for land disposal. It is impermissible to dilute a High-Mercury Subcategory waste to reduce the concentration to less than 260 mg/kg.

For nonwastewater forms of K106 and U151 that are not residues from retorting/roasting and are in the Low-Mercury Subcategory, EPA is transferring the performance of acid leaching treatment followed by sulfide chemical precipitation of K071 nonwastewaters to these inorganic mercury nonwastewaters. The BDAT treatment standard for these wastes is 0.025 mg/l mercury as measured by the TCLP leachate. Residues from this acid leaching process must be evaluated for mercury content to determine whether they must undergo roasting/retorting. Treatment standards for K106 and U151 nonwastewaters are summarized in Table 7-5-A, 7-5-B, and 7-5-C.

7.2.2. P065 and P092 Nonwastewaters

For P065 and P092 nonwastewaters, the BDAT treatment standard is incineration for the carbon-mercury compounds. Alternatively, EPA is promulgating retorting or roasting for P092 nonwastewaters. Incinerator nonwastewater residues equal to or above 260 mg/kg mercury are considered to be in the High-Mercury Subcategory and must be recovered by retorting or roasting. Incinerator nonwastewater residues below 260 mg/kg are considered to belong to the Low-Mercury Subcategory and are not prohibited from land disposal unless they leach mercury above 0.025 mg/l (as measured by the TCLP). Nonwastewater residues from retorting/roasting operations are not prohibited from land disposal unless they leach mercury equal to or above 0.20 mg/l (as measured by the TCLP). Retorting/roasting residues unacceptable for land disposal (i.e., above 0.20 mg/l) are required to comply with the applicable standards for the High- or Low-Mercury Subcategory. P065 and P092 scrubber waters generated from incineration, roasting, or retorting must comply with the 0.030 mg/l wastewater standard (see Table 7-3), which is based on the same performance data used to develop the existing K071 wastewater standard. Treatment standards for P065 and P092 nonwastewaters are shown in Tables 7-6-A, 7-6-B, 7-6-C, 7-6-D and 7-6-E.

7.2.3 D009 Nonwastewaters

The BDAT treatment standard for D009 High-Mercury Subcategory nonwastewaters (i.e., those that contain greater than or equal to 260 mg/kg of mercury) is a combination of the treatment standards for the high-mercury inorganic nonwastewaters and the organic mercury nonwastewaters. EPA has determined that retorting or roasting represents BDAT for D009 high-mercury nonwastewaters containing elemental mercury or inorganic mercury compounds. Although D009 wastes that contain organomercury constituents or contain mercury contaminated with organics can also be retorted/roasted, a pretreatment step may be necessary to allow recovery of mercury. Incineration has been determined to be BDAT for organics in this type of D009 nonwastewater and also for nonwastewater containing organomercury constituents. Since incineration cannot destroy mercury, but instead concentrates mercury in scrubber water or ash to levels not expected to be acceptable for land disposal, the Agency has established additional requirements for the mercury in these residuals. As a result, the treatment standard for D009 high-mercury nonwastewaters is expressed as either retorting/roasting or incineration. Incinerator nonwastewater residues that contain concentrations of mercury greater than or equal to 260 mg/kg are considered to belong to the High-Mercury Subcategory and must be retorted/roasted prior to disposal. Nonwastewater residues from retorting/roasting operations are not prohibited from land disposal unless they leach mercury above 0.20 mg/l (as measured by the TCLP). Retorting/roasting residues unacceptable for disposal (i.e., above 0.20 mg/l TCLP) are required to comply with the appropriate standards for the D009 High- or Low-Mercury Subcategory.

For D009 low-mercury nonwastewaters, EPA is promulgating a treatment standard of 0.20 mg/l, as measured by TCLP (i.e., the toxic characteristic level for mercury). EPA received very few data on the proposed standards for D009 wastes. These data were determined to

represent the treatment of mercury-containing wastes failing the listing criteria for D009, as measured by TCLP. However, several commenters supported the regulatory alternative for setting treatment standards for D009 wastes at the characteristic level. Although data available to EPA indicate that the lower proposed standard (0.025 mg/l) should be achievable for D009, EPA acknowledges the commenters' concerns that a large, diverse number of wastes that qualify as D009 may not be represented by K071 performance data. EPA is thus withdrawing the proposed 0.025 mg/l level (based on K071 performance data). Based on the available data, EPA believes D009 wastes can be treated to the characteristic level by treatment technologies such as stabilization or amalgamation with zinc or tin. EPA is instead promulgating a treatment standard of 0.20 mg/l mercury, as measured by TCLP, for these nonmercury nonwastewaters. BDAT treatment standards for D009 nonwastewaters are summarized in Tables 7-7-A, 7-7-B and 7-7-C.

Several commenters identified a list of D009 wastes that the commenters believe meet EPA's criteria for contaminated soil and debris. The commenters believe that these D009 wastes are not amenable to retorting/roasting. However, they have proposed alternative treatment standards based on the use of a chemical decontamination technology. EPA has been unable to determine whether the alternative chemical decontamination technology represents BDAT for these wastes. The Agency believes such demonstration can be made as part of the ongoing regulatory efforts for contaminated soil and debris. If the technology is demonstrated, EPA may publish revisions to today's standards for these wastes.

7.2.4 Nonwastewaters Containing Radioactive Materials

Information provided to EPA by the U.S. Department of Energy (DOE) indicates the generation of two particular D009 mixed radioactive/ hazardous wastes that contain mercury. This information also suggests

that the BDAT technologies and standards for the corresponding nonradioactive wastes may not be applicable to these mixed wastes. The Agency has therefore promulgated alternative treatment standards for these wastes.

One of the mixed wastes identified is waste elemental mercury contaminated with radioactive tritium (a radioisotope of hydrogen). These wastes are often identified as D009 or U151. EPA has determined that recovery technologies do not represent BDAT for this waste because the Agency lacks data indicating that these processes would be able to separate the mercury from the radioactive material, resulting in recovery of reusable mercury. EPA has identified amalgamation with zinc as a technology that provides significant treatment to these wastes in terms of air emissions (thus greatly reducing the toxicity of the wastes) and also potentially reduces the leachability of mercury by amalgamation. The BDAT for these wastes is amalgamation with zinc, and the treatment standard is amalgamation with zinc as a method of treatment.

The second mixed waste identified is a spent hydraulic oil contaminated with mercury and radioactive tritium. EPA determined that incineration represents BDAT for this waste because incineration is demonstrated for nonradioactive organic mercury nonwastewaters. However, the Agency has modified the nonradioactive organic mercury nonwastewaters standard for this waste by withdrawing the requirement to recover mercury from the inorganic residues generated from incineration of this waste. The Agency is requiring that nonwastewater incineration residues (incinerator ash and wastewater treatment sludge generated from treatment of incineration scrubber waters) comply with a TCLP mercury standard of 0.20 mg/l and that incineration scrubber waters meet the 0.20 mg/l total concentration mercury standard for mercury-containing wastewaters. Treatment standards for mixed radioactive/hazardous mercury wastes are presented in Tables 7-8 and 7-9.

Table 7-1 Calculation of Numerical Treatment Standard for K106, P065, P092 and U151 Wastewaters

Constituent	Accuracy-adjusted treated waste concentrations[a]	Mean treated waste concentration	Variability factor	Treatment standard
Wastewater				
Mercury (mg/l)	0.0295 0.0284 0.0295	0.029	1.05	0.030

[a] See Table 5-2.

Table 7-2 Calculation of Numerical Treatment Standard for Low-Mercury Subcategory Nonwastewaters[a]

Data source	Sample no.	Accuracy-corrected TCLP or EP concentration (mg/l)	Average	Variability factor	Treatment standard (mg/l)
Plant A.1	1	0.0003	0.0043	5.47	0.025
	2	<0.0002			
	3	-			
	4	0.0002			
	5	0.0005			
	6	0.0017			
	7	<0.0002			
Plant A.2	1	-			
	2	-			
	3	0.008			
	4	-			
	5	<0.002			
	6	<0.002			
	7	0.007			
	8	0.002			
	9	<0.002			
	10	0.012			
	11	0.003			
	12	0.004			
	13	0.002			
	14	<0.002			
	15	<0.002			
	16	<0.002			
	17	0.001			
	18	0.003			
	19	<0.001			
	20	<0.002			
	21	<0.002			
	22	<0.002			
	23	<0.002			
	24	<0.002			
	25	<0.001			
	26	<0.001			
	27	<0.002			
	28	<0.002			
	29	<0.002			
	30	<0.001			

[a]Based on transfer of performance data from acid leaching of K071 nonwastewater wastes followed by chemical oxidation and sludge/dewatering/acid washing (USEPA 1988b).

Table 7-2 (Continued)

Data source	Sample no.	Accuracy-corrected TCLP or EP concentration (mg/l)
Plant A.2	31	0.002
	32	<0.001
	33	<0.001
	34	<0.001
	35	<0.001
	36	<0.001
	37	0.001
	38	0.002
	39	0.001
	40	0.002
	41	0.001
	42	0.009
	43	<0.001
	44	0.012
	45	0.001
	46	<0.001
	47	-
	48	-
	49	-
	50	-
	51	-
	52	<0.001
	53	<0.001
	54	<0.001
	55	0.001
	56	<0.001
	57	<0.001
	58	<0.001
	59	<0.001
	60	<0.001
	61	<0.001
	62	<0.001
	63	0.001
	64	<0.001
	65	<0.001
	66	<0.001
	67	<0.001
	68	<0.001
	69	<0.001
	70	<0.001

Table 7-2 (Continued)

Data source	Sample no.	Accuracy-corrected TCLP or EP concentration (mg/l)
Plant A.2	71	<0.001
	72	<0.001
	73	<0.001
	74	0.001
	75	0.004
	76	<0.001
	77	0.001
	78	0.001
	79	0.004
	80	<0.001
	81	<0.001
	82	<0.001
	83	-
	84	-
	85	0.008
	86	<0.001
	87	0.001
	88	0.001
	89	0.007
	90	-
	91	<0.001
	92	0.006
	93	0.005
	94	0.009
	95	0.001
	96	0.002
	97	<0.001
	98	0.002
	99	0.002
	100	0.004
	101	0.002
	102	0.002
	103	0.001
	104	0.001
	105	0.001
	106	0.005
	107	0.005
	108	0.003
	109	0.003
	110	0.002

Table 7-2 (Continued)

Data source	Sample no.	Accuracy-corrected TCLP or EP concentration (mg/l)
Plant A.2	111	<0.001
	112	<0.001
	113	<0.001
	114	<0.001
	115	0.001
	116	<0.001
	117	<0.001
	118	<0.001
	119	<0.001
	120	0.001
	121	-
	122	<0.001
	123	0.003
	124	0.006
	125	<0.001
	126	0.002
	127	<0.001
	128	<0.001
	129	0.002
	130	<0.001
	131	<0.001
	132	<0.001
	133	0.001
	134	<0.001
	135	0.001
	136	<0.001
	137	<0.001
	138	<0.001
	139	<0.001
	140	0.003
	141	0.003
	142	0.001
	143	0.006
	144	0.003
	145	<0.001
	146	0.001
	147	<0.001
	149	<0.001
	150	<0.002
	151	0.003

Table 7-2 (Continued)

Data source	Sample no.	Accuracy-corrected TCLP or EP concentration (mg/l)
Plant A.2	152	-
	153	-
	154	-
	155	0.002
	156	<0.001
	157	<0.001
	158	<0.001
	159	<0.001
	160	0.001
	161	-
	162	-
	163	-
	164	0.011
	165	<0.001
	166	<0.001
	167	-
	168	0.008
	169	0.007
	170	<0.001
	171	<0.001
	172	-
	173	-
	174	-
	175	0.006
	176	0.007
	177	0.001
	178	<0.001
	179	-
	180	0.004
	181	0.008
	182	0.005
	183	0.003
	184	0.001
	185	0.005
	186	0.007
	187	0.002
	188	-
	189	0.010
	190	0.001
	191	0.008

Table 7-2 (Continued)

Data source	Sample no.	Accuracy-corrected TCLP or EP concentration (mg/l)
Plant A.2	192	0.005
	193	0.012
	194	0.002
	195	0.002
	196	-
	197	0.040
	198	-
	199	0.011
	200	-
	201	0.032
	202	0.031
	203	0.014
	204	0.003
	205	0.003
	206	0.012
	207	0.008
	208	0.002
	209	0.007
	210	0.005
	211	0.003
	212	0.012
	213	0.004
	214	0.004
	215	<0.001
	216	0.010
	217	<0.001
	218	0.002
	219	-
	220	0.010
	221	0.010
	222	0.005
	223	0.002
	224	0.002
	225	0.002
	226	0.005
	227	-
	228	0.001
	229	0.003
	230	0.068
	231	0.003

Table 7-2 (Continued)

Data source	Sample no.	Accuracy-corrected TCLP or EP concentration (mg/l)
Plant A.2	232	<0.001
	233	0.009
	234	0.009
	235	0.005
	236	0.005
	237	0.003
	238	0.002
	239	0.008
	240	0.002
	241	0.008
	242	0.032
	243	0.012
	244	0.011
	245	0.003
	246	0.006
	247	0.028
	248	0.003
	249	0.001
	250	0.006
	251	<0.001
	252	<0.001
	253	<0.001
	254	0.001
	255	0.003
	256	0.006
	257	0.002
	258	0.001
	259	0.010
	260	0.006
	261	0.005
	262	0.011
	263	0.007
	264	0.011
	265	0.002
	266	-
	267	0.004
	268	0.021
	269	0.005
	270	0.003
	271	-

Table 7-2 (Continued)

Data source	Sample no.	Accuracy-corrected TCLP or EP concentration (mg/l)
Plant A.2	272	0.009
	273	0.004
	274	0.004
	275	-
	276	0.008
	277	0.002
	278	0.001
	279	<0.001
	280	<0.001
	281	<0.001
	282	0.001
	283	0.006
	284	0.004
	285	0.010
	286	0.002
	287	0.003
	288	0.004
	289	<0.001
	290	<0.001
	291	<0.001
	292	0.001
	293	<0.001
	294	<0.001
	295	<0.001
	296	<0.001
	297	<0.001
	298	<0.001
	299	<0.001
	300	0.008
	301	<0.001
	302	0.001
	303	0.008
	304	0.001
	305	0.001
	306	0.003
	307	<0.001
	308	0.002
	309	<0.001
	310	<0.001
	311	<0.001

Table 7-2 (Continued)

Data source	Sample no.	Accuracy-corrected TCLP or EP concentration (mg/l)
Plant A.2	312	<0.001
	313	0.002
	314	0.008
	315	0.003
	316	0.005
	317	<0.001
	318	<0.001
	319	<0.001
	320	<0.001
	321	0.004
	322	0.001
	323	0.002
	324	0.001
	325	<0.001
	326	<0.001
	327	0.001
	328	0.002
	329	<0.001
	330	0.002
	331	<0.001
	332	0.004
	333	0.004
	334	<0.001
	335	-
	336	0.001
	337	0.001
	338	<0.001
	339	<0.001
	340	<0.001
	341	<0.001
	342	<0.001
	343	0.001
	344	0.001
	345	0.001
	346	0.001
	347	<0.001
	348	0.001
	349	0.001
	350	<0.001
	351	0.003
	352	<0.001
	353	<0.001

Table 7-2 (Continued)

Data source	Sample no.	Accuracy-corrected TCLP or EP concentration (mg/l)
Plant A.2	354	0.004
	355	0.008
	356	0.001
	357	0.001
	358	<0.001
	359	0.008
	360	<0.001
	361	<0.001
	362	0.004
	363	0.002
	364	0.001
	365	<0.001
	366	<0.001
	367	<0.001
	368	0.001
	369	<0.001
	370	<0.001
	371	<0.001
	372	<0.001
	373	0.001
	374	<0.001
	375	<0.001
	376	0.001
	377	0.003
	378	0.011
	379	0.002
Plant B	1	0.0047
	2	0.0208
	3	0.0054
	4	0.0030
	5	0.0096
	6	0.0092
	7	0.0085
	8	0.0175
	9	0.0164
	10	0.0098
	11	0.0140
	12	0.0113
	13	0.0131

Table 7-2 (Continued)

Data source	Sample no.	Accuracy-corrected TCLP or EP concentration (mg/l)
Plant B	14	0.0710
	15	0.0480
	16	0.0090
	17	0.0020
	18	0.0661
	19	0.0087

[a]Note that the treatment standard will be enforced using the TCLP. The value for the treatment standard was rounded to two significant figures at the end of the calculation.

Table 7-3 BDAT Treatment Standard for K106, P065, P092, and U151 Wastewaters

Regulated constituent	Maximum for any single grab sample Total composition (mg/l)
Mercury	0.030

Table 7-4. BDAT Treatment Standard for D009 Wastewaters

Regulated constituent	Maximum for any single grab sample Total composition (mg/l)
Mercury	0.20

Table 7-5-A BDAT Treatment Standard for K106 and U151
[All nonwastewaters in the High-Mercury
Subcategory (i.e., greater than or equal to
260 mg/kg total mercury)]

ROASTING OR RETORTING (RMERC)[a]

[a](RMERC) retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery. The retorting or roasting unit (or facility) must be subject to one or more of the following: (a) a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for mercury; (b) a Best Available Control Technology (BACT) or a Lowest Achievable Emission Rate (LAER) standard for mercury imposed pursuant to a Prevention of Significant Deterioration (PSD) permit; or (c) a State permit that establishes emission limitations (within meaning of Section 302 of the Clean air Act) for mercury. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (e.g., High- or Low-Mercury Subcategories).

Table 7-5-B BDAT Treatment Standard for K106 and U151
[Nonwastewaters that are residues from RMERC and are in the Low-Mercury Subcategory (i.e., less than 260 mg/kg total mercury)]

Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.20

Table 7-5-C BDAT Treatment Standard for K106 and U151
[Nonwastewaters that are not residues from RMERC and are in the Low-Mercury Subcategory (i.e., less than 260 mg/kg total mercury)]

Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.025

Table 7-6-A BDAT Treatment Standard for P065
[All nonwastewaters that are not incinerator residues
and are not residues from RMERC, regardless of mercury content]

INCINERATION OF WASTES WITH ORGANICS AND MERCURY (IMERC)[a]

[a](IMERC) incineration of wastes containing organics and mercury in units operated in accordance with the technical operating requirements of 40 CFR 264 Subpart O and 265 Subpart O). All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (i.e., High- or Low-Mercury Subcategories.)

Table 7-6-B BDAT Treatment Standard for P092
[All nonwastewaters that are not incinerator residues
and are not residues from RMERC, regardless of mercury content]

INCINERATION OF WASTES WITH ORGANICS AND MERCURY (IMERC)[a] OR ROASTING/RETORTING (RMERC)[b]

[a](IMERC) incineration of wastes containing organics and mercury in units operated in accordance with the technical operating requirements of 40 CFR 264 Subpart O and 265 Subpart O). All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (i.e., High- or Low-Mercury Subcategories.)

[b](RMERC) retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery. The retorting or roasting unit (or facility) must be subject to one or more of the following: (a) a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for mercury; (b) a Best Available Control Technology (BACT) or a Lowest Achievable Emission Rate (LAER) standard for mercury imposed pursuant to a Prevention of Significant Deterioration (PSD) permit; or (c) a State permit that establishes emission limitations (within meaning of Section 302 of the Clean Air Act) for mercury. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (e.g., High- or Low-Mercury Subcategories).

Table 7-6-C BDAT Treatment Standard for P065 and P092
[Nonwastewaters that are either incinerator residues or residues from RMERC, and are in the High-Mercury Subcategory (i.e., greater than or equal to 260 mg/kg total mercury)]

ROASTING OR RETORTING (RMERC)[a]

[a](RMERC) retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery. The retorting or roasting unit (or facility) must be subject to one or more of the following: (a) a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for mercury; (b) a Best Available Control Technology (BACT) or a Lowest Achievable Emission Rate (LAER) standard for mercury imposed pursuant to a Prevention of Significant Deterioration (PSD) permit; or (c) a State permit that establishes emission limitations (within meaning of Section 302 of the Clean air Act) for mercury. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (e.g., High- or Low-Mercury Subcategories).

Table 7-6-D BDAT Treatment Standard for P065 and P092
[Nonwastewaters that are incinerator residues (and are not residues from RMERC) that are also in the Low-Mercury Subcategory (i.e., less than 260 mg/kg total mercury)]

Regulated constituent	Maximum for any single grab-sample TCLP (mg/l)
Mercury	0.025

Table 7-6-E BDAT Treatment Standard for P065 and P092
[Nonwastewaters that are residues from RMERC and are in the Low-Mercury Subcategory (i.e., less than 260 mg/kg total mercury)]

Regulated constituent	Maximum for any single grab-sample TCLP (mg/l)
Mercury	0.20

Table 7-7-A BDAT Treatment Standard for D009
[All nonwastewaters that contain mercury and organics (and are not incinerator residues) and are also in the High-Mercury Subcategory (i.e., greater than or equal to 260 mg/kg total mercury)]

INCINERATION OF WASTES WITH ORGANICS AND MERCURY (IMERC)[a] OR ROASTING/RETORTING (RMERC)[b]

[a](IMERC) incineration of wastes containing organics and mercury in units operated in accordance with the technical operating requirements of 40 CFR 264 Subpart O and 265 Subpart O. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (e.g., High- or Low-Mercury Subcategories.)

[b](RMERC) retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery. The retorting or roasting unit (or facility) must be subject to one or more of the following: (a) a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for mercury; (b) a Best Available Control Technology (BACT) or a Lowest Achievable Emission Rate (LAER) standard for mercury imposed pursuant to a Prevention of Significant Deterioration (PSD) permit; or (c) a State permit that established emission limitations (within meaning of Section 302 of the Clean Air Act) for mercury. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (e.g., High- or Low-Mercury Subcategories).

Table 7-7-B BDAT Treatment Standard for D009
[All nonwastewaters that are inorganics (including incinerator residues and residues from RMERC) and are in the High-Mercury Subcategory (i.e., greater than or equal to 260 mg/kg total mercury)]

ROASTING OR RETORTING (RMERC)[a]

[a](RMERC) retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery. The retorting or roasting unit (or facility) must be subject to one or more of the following: (a) a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for mercury; (b) a Best Available Control Technology (BACT) or a Lowest Achievable Emission Rate (LAER) standard for mercury imposed pursuant to a Prevention of Significant Deterioration (PSD) permit; or (c) a State permit that established emission limitations (within meaning of Section 302 of the Clean Air Act) for mercury. All wastewater and nonwastewater residues derived from this process must then comply with the corresponding treatment standards per waste code with consideration of any applicable subcategories (e.g., High- or Low-Mercury Subcategories).

Table 7-7-C BDAT Treatment Standard for D009
[All nonwastewaters in the Low-Mercury Subcategory
(i.e., less than 260 mg/kg total mercury)]

Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.20

Table 7-8 BDAT Treatment Standards for D009 and U151
Elemental Mercury Contaminated with Radioactive Materials

AMALGAMATION WITH ZINC AS A METHOD OF TREATMENT FOR NONWASTEWATERS[a]

[a]Any wastewaters must comply with the appropriate wastewater standard (for D009 or U151).

Table 7-9 BDAT Treatment Standard for D009 Hydraulic Oil Contaminated with Mercury and Radioactive Materials

INCINERATION AS A METHOD OF TREATMENT WITH INCINERATOR RESIDUES MEETING 0.2 MG/L AS MEASURED BY THE TCLP

8. REFERENCES

APHA, AWWA, and WPCF. 1985. American Public Health Association, American Water Works Association, and Water Pollution Control Federation. Standard methods for the examination of water and wastewater. 16th ed. Washington, D.C.: American Public Health Association.

Chemfix. 1989. Data submission for the Third Third Proposed Rule. Docket No. LD12-00073.

Chlorine Institute. 1988. Waste characterization data for K106 wastes, submitted to Office of Solid Waste. Washington, D.C.: U.S. Environmental Protection Agency.

Cosan Chemical Corporation. 1989. Response dated April 13, 1989, to waste questionnaire dated March 9, 1989. Submitted to Office of Solid Waste. Washington, D.C.: U.S. Environmental Protection Agency.

Drake, H.J. 1978. Mercury. In Kirk-Othmer encyclopedia of chemical technology. 3rd ed. Vol. 15, pp. 143-156. New York: John Wiley and Sons.

Easton, D.N. 1988. Management and control of mercury exposure. Am. Lab. 20(7):66-69.

HWTC. 1989a. Hazardous Waste Treatment Council. Data submission for the Third Third Proposed Rule. Docket No. LD12-00050.

HWTC. 1989b. Hazardous Waste Treatment Council. Data submission for the Third Third Proposed Rule. Docket No. LD12-00067.

Iammartino, N.R. 1975. Mercury cleanup routes - II. Chem. Eng. 82(3): 36-37.

IMC. 1982. International Minerals and Chemical Corporation. Delisting petition no. 0321. Submitted by International Minerals and Chemical Corporation, Electrochemicals Division, Orrington, Maine. Submitted to Office of Solid Waste. Washington, D.C.: U.S. Environmental Protection Agency.

McGraw-Hill. 1982. Mercury (element). In McGraw-Hill encyclopedia of science and technology. 5th ed. New York: McGraw-Hill Book Company.

Occidential Chemical Corporation. 1987. Delisting petition for inorganic waste stream K106: wastewater treatment sludge. Submitted by Occidental Chemical Corporation, Muscle Shoals plant, Sheffield, Alabama. Submitted to Office of Solid Waste. Washington, D.C.: U.S. Environmental Protection Agency.

Oxychem. 1989. Comments to the Third Third Proposed Rule. Docket No. LD12-00040.

Oxychem. 1990. Response dated February 23, 1990, to waste questionnaire dated February 8, 1990. Submitted to Office of Solid Waste. Washington, D.C.: U.S. Environmental Protection Agency.

Paintal, A.J. 1990. Memorandum to Jose Labiosa (U.S. Environmental Protection Agency, Office of Solid Waste). Review of December 1989 PEI Associates, Inc. report entitled "Test results for thermal desorption treatment of K106 chlorine production waste." Dated May 7, 1990. Administrative Record - Docket No. LD13REF/7.16.2.1.

PEI Associates. 1989. Test results for thermal desorption treatment of K106 chlorine production waste. Data submission by the Chlorine Institute for the Third Third Proposed Rule. Docket No. LD12-00025.

Perry, R. 1974. Mercury recovery from contaminated waste water and sludges. EPA 660/2-74-086. National Environmental Research Center. Project 12040 HDU. Corvallis, Oreg. U.S. Environmental Protection Agency.

Rosenzweig, M.D. 1975. Mercury cleanup routes - I. Chem. Eng. 82(2): 60-61.

Singer, W. and Nowak, M. 1978. Mercury compounds. In Kirk-Othmer encyclopedia of chemical technology. 3rd ed. Vol. 15, pp. 143-156. New York: John Wiley and Sons.

SRI. 1989. Stanford Research Institute. 1989 directory of chemical producers, United States of America. Menlo Park, Calif. Stanford Research Institute.

U.S. Army. 1984. Military explosives. Department of the Army technical manual TM 9-1300-214, as revised January 30, 1987. Washington, D.C.: Headquarters, Department of the Army.

U.S. Bureau of Mines. 1985. Mercury: A chapter from mineral facts and problems, 1985 edition. Preprint from Bulletin 675. Washington, D.C.: U.S. Department of the Interior.

USEPA. 1984. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Review of national emission standards for mercury. EPA-450/3-84-014. Research Triangle Park, N. C.: U.S. Environmental Protection Agency.

USEPA. 1985. U.S. Environmental Protection Agency, Office of Solid Waste. Characterization of waste streams listed in 40 CFR Section 261: Waste profiles, Volume II. Final report, prepared for Waste Identification Branch, Characterization and Assessment Division, Office of Solid Waste. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1986a. U.S. Environmental Protection Agency, Office of Solid Waste. 1986 national survey of hazardous waste treatment, storage, disposal, and recycling facilities. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1986b. U.S. Environmental Protection Agency, Office of Solid Waste. 1986 national survey of hazardous waste generators. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988a. U.S. Environmental Protection Agency, Office of Solid Waste. Generic quality assurance project plan for Land Disposal Restrictions Program ("BDAT"). Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988b. U.S. Environmental Protection Agency, Office of Solid Waste. Best demonstrated available technology (BDAT) background document for K071. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988c. U.S. Environmental Protection Agency, Office of Solid Waste. Onsite engineering report for Waterways Experiment Station for K106. Draft report. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1989a. U.S. Environmental Protection Agency, Office of Solid Waste. Methodology for developing BDAT treatment standards. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1989b. U.S. Environmental Protection Agency, Office of Solid Waste. Treatment technology background document. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1989c. U.S. Environmental Protection Agency, Office of Solid Waste. Proposed best demonstrated available technology (BDAT) background document for K073. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1989d. U.S. Environmental Protection Agency, Office of Solid Waste. Onsite engineering waste collection visit report for Mercury Refining Company, Albany, New York. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1989e. U.S. Environmental Protection Agency, Office of Solid Waste. Proposed best demonstrated available technology (BDAT) background document for ignitable, reactive, and corrosive wastes. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1989f. U.S. Environmental Protection Agency, Office of Solid Waste. Best demonstrated available technology (BDAT) background document for cyanide wastes. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1989g. U.S. Environmental Protection Agency, Office of Solid Waste. Onsite engineering report of treatment technology performance and operation for McDermitt Mine, McDermitt, Nevada. Final report. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1990. U.S. Environmental Protection Agency, Office of Solid Waste. Final best demonstrated available technology (BDAT) background document for characteristic ignitable wastes (D001), characteristic corrosive wastes (D002), characteristic reactive wastes (D003), and P and U wastes containing reactive listing constituents. Washington, D.C.: U.S. Environmental Protection Agency.

Versar Inc. 1986. Summary of available waste composition data from review of literature and data bases for use in treatment technology application and evaluation for "California List" waste streams. Contract No. 68-01-7053, final report for Office of Solid Waste. Washington, D.C.: U.S. Environmental Protection Agency.

Weast, R.C., ed. 1977. CRC handbook of chemistry and physics. 58th ed. Cleveland, Ohio: CRC Press, Inc.

APPENDIX A

QUALITY ASSURANCE/QUALITY CONTROL DATA

APPENDIX A
QUALITY ASSURANCE/QUALITY CONTROL DATA

A.1 Analytical Methods

The analytical methods used for analysis of the regulated constituents identified in Section 5 are listed in Table A-1. SW-846 methods (EPA's Test Methods for Evaluating Solid Waste; Physical/Chemical Methods, SW-846, Third Edition, November 1986) are used in most cases, except for the TCLP extraction procedure (published in 51 FR 40643, November 7, 1986, as Appendix I to Part 268 - Hazardous Waste Management System; Land Disposal Restrictions; Final Rule).

Specific procedures or equipment used for preparing or analyzing the regulated constituents when alternatives or equivalents are allowed by SW-846 are listed in Table A-2.

A.2 Accuracy Determination

The accuracy determination for a pollutant is based on the matrix spike recovery values. The accuracy correction factors were determined in accordance with the general methodology (see USEPA 1989a). For example, for most BDAT list metals, actual spike recovery data were obtained for each individual TCLP sample and the lowest value was used to calculate the accuracy-corrected value. Table A-3 presents the matrix spike recoveries and the accuracy correction factor used to correct the concentration of mercury in K071 mercury-containing wastewaters and nonwastewaters.

Table A-1 Analytical Methods for K071 Wastewaters

Analysis/Methods	Method
Mercury in Liquid Waste (Manual Cold-Vapor Technique)	7470
Mercury in Solid or Semisolid Waste (Manual Cold-Vapor Technique)	7471
TCLP	40 CFR Part 268, Appendix I

Table A-2 Procedures or Equipment Used in Mercury Analysis When Alternatives or Equivalents Are Allowed in the SW-846 Methods

Constituent	Analysis method	Equipment	Alternatives or equivalents allowed by SW-846 method	Specific procedures or equipment used
Mercury	7470 7471	Perkin Elmer 50A	• Operate equipment according to instructions of instrument manufacturer.	• Equipment was operated using procedures specified in Perkin Elmer 50A Instructions Manual.
			• Use cold vapor apparatus as described in SW-846 or an equivalent apparatus.	• Mercury was analyzed by cold-vapor method using the apparatus as specified in SW-846, except that there was no scrubber.
			• Prepare samples using the water bath method or the autoclave method, both described in SW-846.	• Samples were prepared using the water bath method.

Source: USEPA 1988b. Table B-2.

Table A-3 Matrix Spike Recoveries Used to Correct Analytical Data for K071 Mercury-Containing Wastewaters and Nonwastewaters

BDAT constituent	Original amount found (μg/l)	Sample Set #6			Sample Set #6 Duplicate			Accuracy correction factor[b]
		Spike added (μg/l)	Spike result (ug/l)	Percent recovery[a]	Spike added (μg/l)	Spike result (μg/l)	Percent recovery[a]	
Mercury	1.6	4.0	5.4	95	4.0	5.5	98	1.05

[a]Percent Recovery = [(Spike Result - Original Amount)/Spike Added].
[b]Accuracy Correction Factor = 100/Percent Recovery (using the lowest percent recovery value).

Source: USEPA 1988b. Table B-4.

APPENDIX B

PROPERTIES AND MAJOR USES OF THE PRINCIPAL COMPOUNDS OF MERCURY

APPENDIX B

PROPERTIES AND MAJOR USES OF THE PRINCIPAL COMPOUNDS OF MERCURY

The attached table presents physical-chemical properties and major uses of the principal mercury compounds. This table was taken from McGraw-Hill (1982).

Table B-1 Principal Compounds of Mercury

Compound and formula	Properties and uses
Mercury(II) acetamide, $Hg(NHCOCH_3)_2$	White crystals; soluble in water and alcohol; mp 198°C
Mercury(II) acetate, $Hg(CH_3COO)_2$	White powder; soluble in alcohol and dilute acids; hydrolyzes in boiling water, yielding HgO
Ammonium tetrachloromercurate(II) dihydrate, $(NH_4)_2(HgCl_4)\cdot 2H_2O$	White crystalline powder; soluble in water; slightly soluble in alcohol
Mercury(II) diammine chloride, $Hg(NH_3)_2Cl_2$	Fusible white crystalline precipitate; soluble only in hydrochloric acid with decomposition
Mercury(II) chloride, ammoniated, $HgNH_2Cl$	Infusible precipitate; white powdery lumps or powder; soluble in hydrochloric acid only; earthy metallic taste; consists of chains $(—Hg—NH_2—)_n^{n+}\ n\ Cl^-$
Mercury(II) arsenate, $HgHAsO_4$	Yellow powder; insoluble in water; soluble in hydrochloric acid
Barium tetrabromomercurate(II), $Ba(HgBr_4)$	Colorless crystalline powder; very hygroscopic; soluble in water
Mercury(II) benzoate, $Hg(C_6H_5COO)_2\cdot H_2O$	White crystals, slightly soluble in water and alcohol; mp 165°C
Mercury(II) bromide	White rhombic crystals; soluble in alcohol, ether, acetone, and ethyl acetate; sparingly soluble in water; mp 238°C; bp 319°C; specific electrical conductivity at 242°C = 1.45×10^{-4} $ohm^{-1}\ cm^{-1}$; vapor pressure at 200°C, 24.1 mm Hg, at 260°C, 200 mm Hg; very high cryoscopic constant (similar to camphor) of 36.7°C for 1 *M* in 1000 g of $HgBr_2$
Mercury(II) chloride, $HgCl_2$	White crystals or powder; soluble in water, alcohol, ether, pyridine, and methylacetate; mp 265°C; bp 303°C; solid substance contains $HgCl_2$ molecules, as do solutions of $HgCl_2$ in water or organic solvents; very strong poison (0.2–0.4 g is deadly; breathing of dust should be avoided)
Copper(I) tetraiodomercurate(II), $Cu_2(HgI_4)$	Dark-red crystalline powder; insoluble in water and alcohol; changes its color from red to black at 71°C, and assumes red color again if cooled to room temperature
Mercury(II) cyanide, $Hg(CN)_2$	Colorless crystalline prisms, darkened by light; soluble in water and alcohol; decomposes on heating into metallic mercury and cyanogen; solution in water contains practically no free ions
Mercury(II) fluoride, HgF_2	Transparent crystals; moderately soluble in water and alcohol; hydrolyzes in water solutions; decomposes at mp 645°C
Mercury(II) iodate, $Hg(IO_3)_2$	Amorphous white powder; soluble in hydrochloric, hydrobromic, and hydroiodic acids, and in water containing sodium chloride or potassium iodide; insoluble in water and alcohol
Mercury(II) iodide, HgI_2	Red crystals, tetragonal, turn to yellow rhombic crystals when heated above 127°C, returning to red modification on cooling; insoluble in water; soluble in ether and benzene; yellow form soluble in alcohol; both modifications soluble in aqueous solutions of sodium thiosulfate or potassium iodide; mp 421°C; bp 349°C
Mercury(II) lactate, $Hg(C_3H_5O_3)_2$	White crystalline powder; decomposes on heating; soluble in water
Mercury(II) nitrate, $Hg(NO_3)_2\cdot H_2O$	Mp 79°C with decomposition; colorless crystals or, if slightly hydrolyzed by water, yellowish powder; soluble in nitric acid; insoluble in alcohol; powerful vesicant
Mercury(II) oxide, HgO	Decomposes above 400°C into mercury and oxygen; soluble in acids; insoluble in alcohol and ether; exists in finely divided form which is more reactive than the crystallized red form; both forms have the same crystal structure with chains $(—Hg—O—)_n$
Mercury(II) oxidcyanide, NC—Hg—O—Hg—CN	Explodes on heating; white crystalline powder; slightly soluble in water; used as antiseptic solution (1 : 5000)
Mercury(II)-chlorate(VII), $Hg(ClO_4)_2\cdot 6H_2O$	Colorless crystals; hygroscopic; soluble in acid solutions
Mercury(II) phosphate, $Hg_3(PO_4)_2$	Heavy white or yellowish powder; soluble only in acids, not soluble in water
Potassium tetracyanomercurate(II), $K_2[Hg(CN)_4]$	Colorless crystals; very poisonous; soluble in water and alcohol
Potassium tetraiodomercurate(II), $K_2(HgJ_4)$	Nessler's reagent; soluble in water; crystallizes water-free in yellow crystals; hydrates with 1, 2, or 3 moles of water are known
Mercury(II) salicylate, $Hg(C_6H_4O)COO$	White powder; soluble in warm alkali halide solutions
Silver(I) tetraiodomercurate(II), $Ag_2(HgI_4)$	Yellow powder; becomes red at 40–50°C; insoluble in water and dilute acids; soluble in aqueous solutions of potassium cyanide and potassium iodide
Mercury(II) subsulfate, $2HgO\cdot HgSO_4$	Heavy lemon-yellow powder; insoluble in water; soluble in acids
Mercury(II) sulfate, $HgSO_4$	White crystalline powder; hydrolyzes with water; insoluble in alcohol; soluble in acids
Mercury(II) sulfide, black, HgS	Black powder; insoluble in water, acids, and organic solvents; soluble in sodium sulfide solution; sublimes at 446°C, yielding the red form of HgS, which possesses another crystal structure; the black sulfide is formed by passing hydrogen sulfide gas into mercury salt solutions or by reaction between metallic mercury and sulfur

(*continued*)

Table B-1 (continued)

Compound and formula	Properties and uses
Mercury(II) sulfide, red, HgS	Cinnabar; red crystals; insoluble in water, acids, and organic solvents; solvents; sublimes at 446°C; red form of HgS is the main mercury ore
Mercury(II) thiocyanate, $Hg(SCN)_2$	White powder; only slightly soluble in water; soluble in alcohol; decomposes on heating
Mercurochrome, $C_{20}H_7O_3Br_2Na_2HgOH \cdot 3H_2O$	Disodium 2,7-dibromo-4-hydroxymercurifluorescein; green scales; soluble in water; insoluble in alcohol, ether, and chloroform; used in 2% aqueous solution as a general antiseptic
Mercury(I) acetate, $Hg_2(CH_3COO)_2$	Colorless plates; decomposes by light or in boiling water into Hg and $Hg(CH_3COO)_2$; slightly soluble in water; insoluble in alcohol and ether
Mercury(I) bromide, Hg_2Br_2	White powder or tetragonal crystals; becomes yellow on heating and white again on cooling; sublimes at 340–350°C; mp 405°C
Mercury(I) chlorate, $Hg_2(ClO_3)_2$	White crystals; explodes with combustible substances; mp 250°C (decomposition); soluble in water and alcohol
Mercury(I) chloride, Hg_2Cl_2	Calomel; white rhombic crystals; insoluble in water, alcohol, and ether; mp 303°C; bp 384°C; becomes black with ammonia ($Hg_2Cl_2 + 2NH_3 \rightarrow Hg + HgNH_2Cl + NH_4Cl$) by yielding finely divided metallic mercury
Mercury(I) chromate, Hg_2CrO_4	Brick-red powder decomposes on heating to yield Cr_2O_3; insoluble in water and alcohol; soluble in concentrated nitric acid
Mercury(I) iodide, Hg_2I_2	Yellow amorphous powder; becomes greenish in light ($Hg_2I_2 \rightarrow Hg + HgI_2$); orange on heating, but yellow again on cooling; insoluble in water, alcohol, and ether; sublimes at 110–120°C; mp 290°C (partial decomposition); bp 310°C
Mercury(I) nitrate, $Hg_2(NO_3)_2 \cdot 2H_2O$	Short prismatic crystals; soluble in small quantities of warm water, in nitric acid, in boiling carbon disulfide, and in methylamine, and slightly soluble in benzonitrile; hydrolyzes with large quantities of water; mp 70°C with decomposition
Mercury(I) sulfate, Hg_2SO_4	White crystalline powder; almost insoluble in water; soluble in hot sulfuric acid and in dilute nitric acid; decomposes on heating
Mercury dimethyl, $Hg(CH_3)_2$	Colorless volatile liquid; very strong poison; bp 92°C; density at 19°C is 3.084 g/cm³
Mercury diphenyl, $Hg(C_6H_5)_2$	Colorless crystals; mp 122°C; decomposes on heating into mercury and diphenyl
Mercury fulminate, $Hg(CNO)_2$	Dark-brown crystalline powder; explodes when dry under the slightest shock and by heating
Mercury methyl chloride, CH_3HgCl	Colorless plates; mp 170°C; very strong poison
Millon's base, $(Hg_2N)OH \cdot 2H_2O$	Yellow powder; insoluble in water and organic solvents; exchanges OH^- ions with halide ions, when in contact with aqueous alkali halide solutions; consists of NHg_4-tetraeders with positive charge at the N atoms (the NHg_4-tetraeders are linked together like the SiO_4-tetraeders in SiO_2, forming a three-dimensional network) and OH^- ions; the H_2O molecules are in holes of the network
Mercury thiochloride, $Hg_3S_2Cl_2$	Yellow powder; insoluble in water
Mercury oxide chloride, $[O(HgCl)_3]Cl$	Colorless crystals; insoluble in cold water; exchanges 1 Cl^- ion with F^- ions
Mercury(II) oxalate, HgC_2O_4	White powder; insoluble in water; used for Eder's solution (decomposition with light)

Source: McGraw-Hill (1982)